

# NOLAN CREEK

## Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218



*Prepared for:*

**Texas Commission on Environmental Quality  
Nonpoint Source Program CWA §319(h)  
Contract No. 582-14-30061**

*Prepared by:*

**Texas Institute for Applied Environmental Research**

**TR1409**

**For Public Review  
July 2015**

## ACKNOWLEDGEMENTS

Financial support for this report was provided through a Texas Commission on Environmental Quality (TCEQ) Nonpoint Source Program Clean Water Act §319(h) grant for the project, *Assessment of Water Quality and Watershed Based Planning for Nolan Creek/South Nolan Creek* (Contract No. 582-13-30061, U.S. Environmental Protection Agency Federal ID #99614617). This report was prepared by Anne McFarland, senior research scientist at TIAER, with assistance from Todd Adams, research associate at TIAER, with assistance from the City of Killeen. The authors would also like to thank input from stakeholders in the Nolan Creek Watershed Partnership.

## SUMMARY

This Data Inventory Report was prepared as a first step in satisfying Element A of the EPA *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*. Element A involves identification of causes and sources of pollution within a watershed that will need to be controlled to achieve estimated load reductions. Within this project, Element A is being addressed in three phases: Phase 1 involves creation of the data inventory and identification of data gaps, Phase 2 involves data collection and analysis to address data needed to evaluate loadings, and Phase 3 provides loading estimates by source and estimate load reductions. Each phase builds upon the preceding phase and separate reports will document the findings of each phase. This data inventory, as Phase 1 in characterizing the Nolan Creek/South Nolan Creek watershed, summarizes existing data focusing on bacteria sources as the identified water quality impairment and discusses data gaps that need to be filled to complete the watershed characterization. Phase 2 of this project addresses some of these data gaps through the project's monitoring program, and Phase 3 will estimate loadings within the watershed by source and sub-watershed using load duration curves and spatial modeling tools.

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For more information about this document or any other document TIAER produces, send email to [info@tiaer.tarleton.edu](mailto:info@tiaer.tarleton.edu). More information about the Nolan Creek/South Nolan Creek project can be accessed from the project website at: <http://www.killeentexas.gov/nolancreekwatershed>.

Cover photograph is South Nolan Creek at Roy Reynolds Road (station 11913) taken on June 4, 2013.

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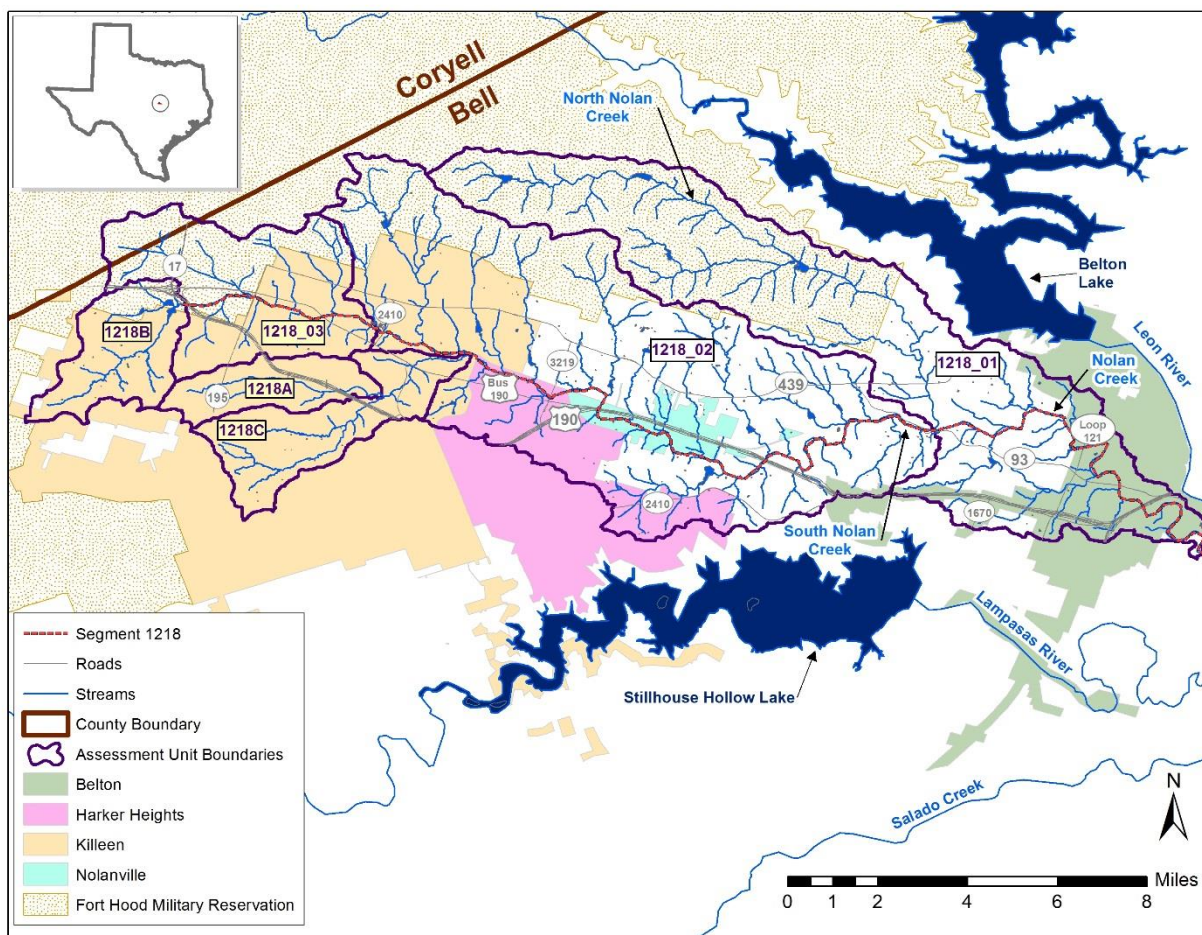
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## SECTION 1

### The Watershed and Water Body Conditions

The Nolan Creek/South Nolan Creek watershed comprises 72,800 acres and is located almost completely within Bell County with only a small portion extending into Coryell County (Figure 1-1). South Nolan Creek has its headwaters near the City of Killeen and converges with North Nolan Creek to the west of Belton to form Nolan Creek. Nolan Creek then passes through the City of Belton and converges with the Leon River as part of the Brazos River Basin.

Municipalities within the watershed include Killeen, Harker Heights, Nolanville, and Belton. The Fort Hood Military Reservation also covers much of the northern portion of the watershed.



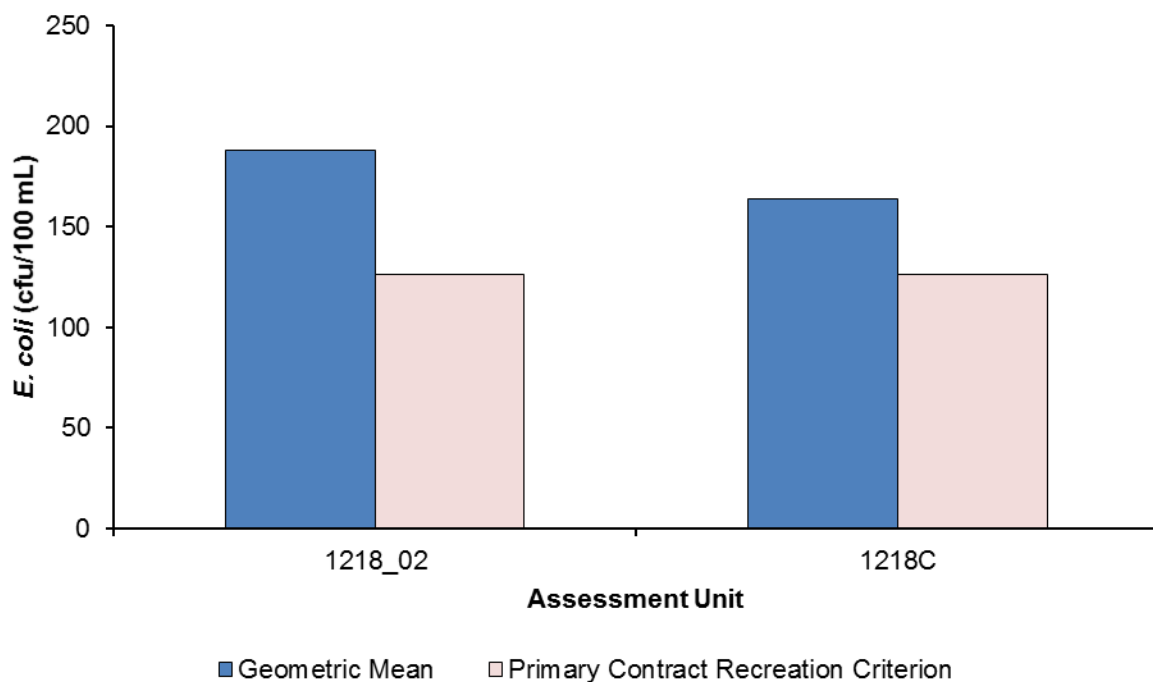
**Figure 1-1** Watershed and assessment units associated with Segment 1218, Nolan Creek/South Nolan Creek. Inset shows watershed location within the State of Texas.

Segments and assessment units (AUs) identified by the Texas Commission on Environmental Quality (TCEQ) in Figure 1-1 include the following:

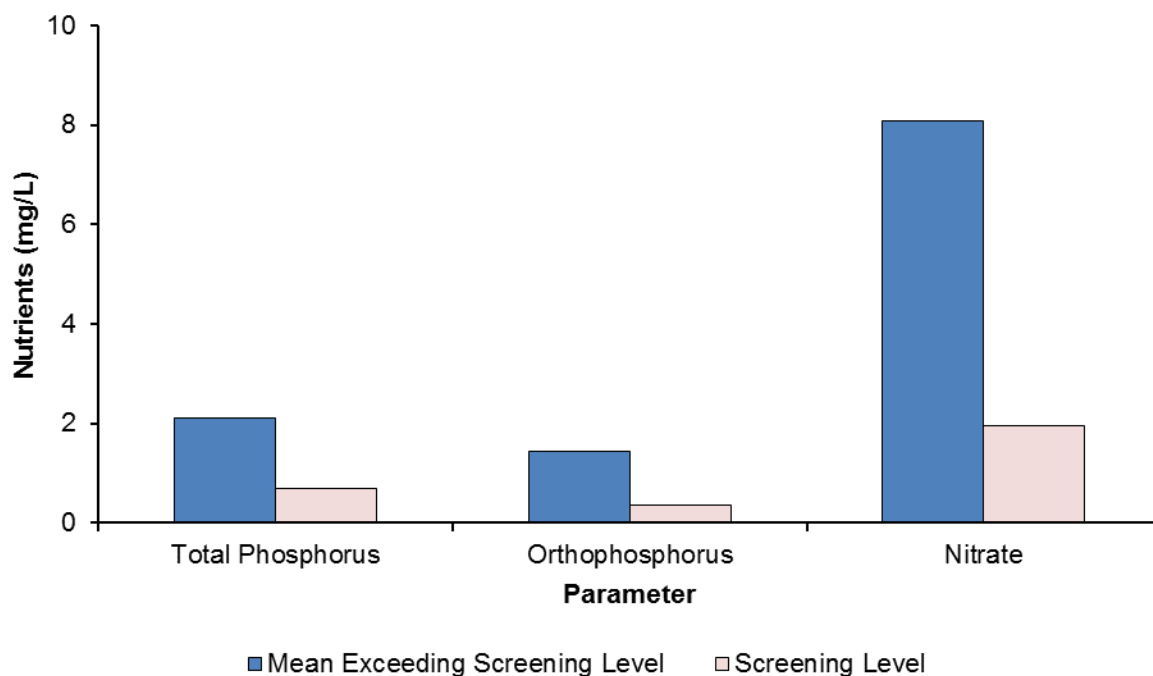
- 1218: Nolan Creek/South Nolan Creek - from confluence with the Leon River in Bell County to a point 100 meters upstream to the most upstream crossing of US 190 and Loop 172 in Bell County.
- 1218\_01: Portion of Nolan Creek from the confluence with the Leon River upstream to confluence with North Nolan/South Nolan Creek fork in Bell County.
- 1218\_02: Portion of South Nolan Creek from confluence with North Nolan/Nolan Creek fork upstream to confluence with Liberty Ditch in City of Killeen in Bell County.
- 1218\_03: Portion of South Nolan Creek from confluence with Liberty Ditch in Killeen upstream to a point 100 meters upstream of the most upstream crossing of US 190 near the intersection of US 190 and Loop 172 in Bell County.
- 1218A: Unnamed Tributary to Little Nolan Creek - from the confluence with Little Nolan Creek upstream to headwaters in the City of Killeen, Bell County.
- 1218B: South Nolan Creek - from 100 meters upstream of the most upstream crossing of US 190 near the intersection of US 190 and Loop 172 upstream to headwaters in the City of Killeen, Bell County.
- 1218C: Little Nolan Creek - from the confluence with Nolan Creek/South Nolan Creek upstream to headwaters in the City of Killeen, Bell County.

## **2012 Texas Water Quality Inventory**

The 303(d) List within the 2012 Texas Water Quality Inventory includes bacteria as an impairment for assessment units (AUs) 1218\_02 and 1218C for primary contact recreation (TCEQ, 2013a). The draft 2014 Texas Water Quality Inventory continues to list these same impairments (TCEQ, 2014a). To assess an impairment for primary contact recreation, the geometric mean of water quality samples is compared to the criterion of 126 cfu/100 mL for primary contact recreation (Figure 1-2). Segment 1218\_02 was first listed as impaired for bacteria in 1996, while water body 1218C was not listed until 2010. In addition to the bacteria impairment, concerns for elevated nitrate, total phosphorus, and orthophosphorus concentrations are noted for AU 1281\_02 in the 2012 Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d) (Figure 1-3; TCEQ, 2013b). These same concerns are also listed in the draft 2014 report (TCEQ, 2104a). To assess nutrient concerns, nutrient concentrations are compared to screening levels representing the 85<sup>th</sup> percentile values for each parameter derived from statewide surface water quality monitoring (SWQM) data for freshwater streams. A concern for nutrients is indicated if the screening level is exceeded 20 percent or more of the time using a binomial method (TCEQ, 2012b). The Brazos River Authority (BRA), a Clean Rivers Program partner with TCEQ, notes these same impairments and concerns in the 2012 Brazos River Basin Summary Report for Segment 1218 (BRA, 2013).



**Figure 1-2** Comparison of geometric mean bacteria concentrations with primary contact recreation criterion for impaired AUs within Segment 1218. Source: 2012 Texas Water Quality Inventory (TCEQ, 2013c).



**Figure 1-3** Comparison of average nutrient concentrations above screening levels with nutrient screening levels for AU 1218\_02. Source: 2012 Texas Water Quality Inventory (TCEQ, 2013c).

The Texas Water Quality Inventory is a biennial report that presents the status of the State's waters based on historical surface and groundwater data and is prepared in response to Section 305(b) of the Federal Clean Water Act. The 303(d) List is developed from the water quality inventory, as required under Sections 303(d) and 304(a) of the Federal Clean Water Act, and identifies water bodies within Texas that do not meet water quality standards. The main mechanism for addressing pollutants on the 303(d) List is through development of a Total Maximum Daily Load (TMDL), which indicates the maximum amount of a pollutant that can enter a water body and still allow that water body to meet water quality standards. Other types of actions may include verification of use attainment, revision of the designated use category for recreation, or development of a watershed protection plan (WPP).

In Texas, other actions may be needed prior to development of a TMDL, and these actions are indicated by the subcategory assigned to the water body. All water bodies on the 303(d) List are considered a category 5, indicating that the water body does not meet applicable water quality standards or is threatened for one or more designated uses by one or more pollutants. Subcategories are indicated as follows:

- Category 5a indicates a TMDL is underway, scheduled, or will be scheduled.
- Category 5b indicates a review of the water quality standard for the water body will be conducted before a TMDL is scheduled.
- Category 5c indicates that additional data and information will be collected before a TMDL is scheduled.

The impaired AUs within the Nolan Creek/South Nolan Creek watershed have both been assigned to Category 5b with regard to bacteria indicating that a review of the water quality standards for this water body will be conducted before a TMDL is scheduled. This standards review will involve assessing the recreational use of Segment 1218 and whether changes in the use category should occur. In 2010, a recreational use attainability analysis (RUAA) survey report was published, but as of May 18, 2015, no recommendations have been made by TCEQ regarding Segment 1218 (<http://www.tceq.texas.gov/waterquality/standards/ruaas/brazospt1>).

## **Texas Standards for Recreational Use**

In assessing the suitability of a water body for recreational use, bacteria are used as an indicator of fecal contamination by warm-blooded animals. Fecal coliforms are gram negative, facultative anaerobic, lactose fermenting bacteria that are commonly found in the intestines of homeotherms (Talaro and Talaro, 1999). *Escherichia coli*, a species of coliform bacteria, is often used as an indicator of the possible presence of fecal pathogens in water, because its concentration in water is relatively easy to measure, and it is often the most abundant species of the fecal coliform bacteria (Talaro and Talaro, 1999). *E. coli* concentrations are typically expressed as a most probable number per 100 milliliters of water (MPN/100 mL) or the number of colony forming units per 100 milliliters of water (cfu/100 mL). For Texas, the water quality criteria for bacteria are expressed as the number of bacteria per 100 mL of water (in terms of colony forming units, most probable number, or other applicable reporting measures), so the units MPN/100 mL and cfu/100 mL are used interchangeably.

Within the 2012 Texas Water Quality Inventory, all classified water bodies are presumed to support contact recreation and any change in that designation requires a comprehensive study. Contact recreation is defined as recreational activities involving a significant risk of ingestion of water, such as swimming or wading by children. In 2000, Texas adopted a geometric mean of 126 *E. coli* per 100 mL of water as the criterion for assessing the use of contact recreation in freshwaters as part of the Texas Water Quality Standards (TWQS). Prior to this change, a geometric mean of 200 fecal coliform per 100 mL of water had been used as the criterion for contact recreation. With this change in 2000 of the TWQS, fecal coliform temporarily continued to be collected as an indicator to allow a transition period. Prior to 2004, most bacteria data were reported as fecal coliform rather than *E. coli* as TCEQ gradually phased from fecal coliform to *E. coli* as the primary indicator of bacteria in freshwaters.

More recently in June 2010, TCEQ adopted further revisions to the criteria for evaluating contact recreation by expanding from two categories (contact and noncontact recreation) to four categories (primary contact recreation [PCR], secondary contact recreation 1 [SCR1], secondary contact recreation 2 [SCR2], and noncontact recreation [NCR]) with corresponding changes to numeric criterion associated with each category (Table 1-1). These additional categories were made into rules as part of the TWQS in July 2010, which were reviewed and approved by EPA in June 2011. The default category is primary contact recreation unless it can be demonstrated with a Recreational Use Attainability Analysis (RUAA) that a different category of recreational use is more appropriate.

## Previous Studies

As part of the review of the water quality standards for Segment 1218, a Recreational Use Attainability Analysis (RUAA) was conducted and the report is available on TCEQ's website under RUAA's conducted for the Brazos River and available for public review (<http://www.tceq.texas.gov/waterquality/standards/ruaas/ruaasbrazos>). As of May 2015, the TCEQ has not made any recommendations regarding a change in the recreational use categorization of Segment 1218, so unless a change is recommended and then approved by EPA, Segment 1218 remains classified for primary contact recreation. The RUAA report indicates a large number of public road crossings and several parks along Segment 1218 allowing the public easy access to the creek in several locations (Winemiller et al., 2010). Kayaking along about a 7 mile stretch from Backstrom Crossing off Farm to Market (FM) 93 east of Nolanville to US Interstate 35 in Belton is described in *Texas Whitewater* (Daniel, 2004) as a destination for encountering Class II-III rapids when water levels are elevated. The RUAA report also indicates that Texas Parks and Wildlife Department (TPWD) for the last several years has stocked Rainbow trout (*Oncorhynchus mykiss*) for fishing during the winter months into Nolan Creek near Yettie Polk and Confederate Parks within the City of Belton. The most recent fish stocking occurred in December 2013 (TPWD, 2013).

The current project builds upon a FY04 319(h) grant project conducted by the City of Killeen entitled, *Assessment and Targeting of Bacterial Sources in the South Nolan Creek Watershed*, which assessed water quality conditions and impairments within the upper portion of the South Nolan Creek watershed (Nett and Flowers, 2008). This previous 319 project focused on the uppermost portion of Segment 1218 including AUs 1218A, 1218B, 1218C, 1218\_03, and the upper most portion of 1218\_02, all which contain portions of the City of Killeen (Figure 1).

**Table 1-1** Recreation use categories and numeric criteria. Source: TCEQ (2010).

<b>Contact Category</b>	<b>Basic Definition</b>	<b>Criteria as Geometric Mean of <i>E. coli</i>/100 mL</b>
<b>Primary Contact Recreation (PCR)</b>	Activities that are presumed to involve a significant risk of ingestion of water (e.g. wading by children, swimming, water skiing, diving, tubing, surfing, and the following whitewater activities: kayaking, canoeing, and rafting).	126
<b>Secondary Contact Recreation (SCR1)</b>	Activities that commonly occur but have limited body contact incidental to shoreline activity (e.g. fishing, canoeing, kayaking, rafting and motor boating). These activities are presumed to pose a less significant risk of water ingestion than primary contact recreation but more than secondary contact recreation 2.	630
<b>Secondary Contact Recreation (SCR2)</b>	Activities with limited body contact incidental to shoreline activity (e.g. fishing, canoeing, kayaking, rafting and motor boating) that are presumed to pose a less significant risk of water ingestion than secondary contact recreation 1. These activities occur less frequently than secondary contact recreation 1 due to physical characteristics of the water body or limited public access.	1,030
<b>Noncontact Recreation (NCR)</b>	Activities that do not involve a significant risk of water ingestion, such as those with limited body contact incidental to shoreline activity, including birding, hiking, and biking. Noncontact recreation use may also be assigned where primary and secondary contact recreation activities should not occur because of unsafe conditions, such as ship and barge traffic.	2,060

The goal of this previous project was to confirm whether the City of Killeen was contributing to the elevated bacteria concentrations, and if so, to what degree, and to identify priority sub-basins for implementation of control practices. As part of City of Killeen's project, monthly monitoring was conducted at nine stations for bacteria from October 2006 through February 2008. On three occasions about six months apart, nutrients, metals, dissolved oxygen, biological oxygen demand, temperature, pH, conductivity, flow, and water clarity were monitored at five sites. Storm monitoring was conducted at one station (11913 off Roy Reynolds Rd) with wet-weather

samples from nine events analyzed for nutrients, total suspended solids, biological oxygen demand, and oil and grease. In conjunction with the water quality monitoring, potential sources of bacteria were examined. The monitoring results found low bacteria levels for South Nolan Creek above 38<sup>th</sup> Street and confirmed a bacteria impairment downstream between Twin Creek Drive and Ann Boulevard within the City of Killeen. Elevated bacteria concentrations were also noted along Long Branch and Little Nolan Creek. These findings led to the partitioning of Nolan Creek/South Nolan Creek into three main assessment units (AUs), and three additional water bodies for assessment purposes (Figure 1-1). The study indicated that bacteria were not a problem in much of the headwaters as defined by AU 1218\_03 allowing future efforts to focus on the impaired areas now defined by AUs 1218\_02 and 1218C.

In comparing results from the City of Killeen monitoring with information regarding potential sources, a significant positive correlation was found between the number of septic tanks in the drainage area above sampling stations and bacteria concentrations (Nett and Flowers, 2008). Control practices were recommended for target areas along Long Branch and Little Nolan Creek that included a septic tank elimination program (STEP) and targeted public education regarding septic tank maintenance. Dry weather screening for illicit discharges was also recommended as well as public education throughout the watershed regarding appropriate disposal of pet waste. Implementation of these control practices has become part of the City of Killeen's storm water management program, and the stakeholder group developed has helped lead to the current project, which extends the examination of elevated bacteria concentrations to more downstream portions of Nolan Creek/South Nolan Creek.

### **Current Project and Purpose**

The current project focuses on the impaired assessment units 1218\_02 along South Nolan Creek and 1218C along Little Nolan Creek, but also includes data gathering efforts throughout the Nolan Creek/South Nolan Creek watershed. The objective of this project is to build on previous monitoring and source identification efforts conducted by the City of Killeen focusing on impaired sections and extending efforts downstream to include the cities of Harker Heights, Nolanville, and Belton. The Fort Hood Military Reservation also covers much of the watershed and almost the entire watershed is within Bell County. The goal of this project is to provide watershed stakeholders and affected agencies with enough information to determine how to address these bacteria impairments.

This report provides a building block towards meeting the project goal of identifying causes and sources of pollution in the Nolan Creek/South Nolan Creek watershed by providing an inventory of existing data to aid in watershed planning efforts. Because bacteria is the impairment, this report focuses primarily on data related to bacteria and potential bacteria sources within the watershed, but also considers the nutrient concerns as noted in the 2012 Texas Water Quality Inventory.

This Data Inventory Report was prepared as a first step in satisfying Element A of the EPA *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (EPA, 2008). Element A involves identification of causes and sources of pollution within a watershed that will need to be controlled to achieve estimated load reductions. Within this project, Element A is being addressed in three phases: Phase 1 involves creation of the data inventory and

identification of data gaps, Phase 2 involves direct data collection needed to evaluate loadings sources and loadings throughout the watershed, and Phase 3 will provide loading estimates by source at the sub-watershed level as well as estimates of needed load reductions.

To develop estimates of loadings and sources for Phase 3, the Spatially Explicit Load Enrichment Calculation Tool (SELECT) will be used. This tool was developed jointly by the Spatial Sciences Laboratory (SSL) and Department of Biological and Agricultural Engineering at Texas A&M University as a screening model to spatially depict and estimate potential bacteria loads from various sources within a watershed (see Teague et al., 2009). Use of SELECT involves developing an inventory of potential bacterial sources (e.g., point discharges, septic systems, livestock, deer, feral hogs, and pets) and then distributing the potential loads from these sources across the watershed based on land use and source type. Combining land use and source loading data, SELECT then generates a spatial display by subwatershed of potential bacteria loadings that can be used to target potential “hot spots” and identify dominant sources. While a useful tool, SELECT has limitations in that it can only depict those sources for which density data are readily available. Some sources not addressed by SELECT include contributions from raccoons, opossums, and birds (Borel et al., 2015). While SELECT was developed for rural watersheds, the urban area, as represented by point sources from WWTFs and MS4 areas, can also be considered with some modifications (e.g., Ling et al., 2012). While SELECT is a spatial model, it does not simulate runoff or actual loadings, but presents potential loadings for the sources for which input data are provided. This report will aid in developing the inventory of inputs for SELECT, which generally include spatial data on land use/land cover, soils, census data, municipal boundaries, and the location of wastewater treatment facility outfalls. If available, the location of septic systems is used, although this information is generally unavailable or not easily input into the spatial coordinates needed by SELECT, but can be estimated using a combination of land use and census data.

Besides use of SELECT and relating various sources to instream monitoring data, load duration curves (LDCs) will also be developed for at least four locations within the watershed to aid in the identification of sources and needed load reductions. Load duration curves are a simple method for obtaining an estimate of loadings under varying flow regimes (EPA, 2007; Cleland, 2003). The data needed for developing LDCs for the Nolan Creek/South Nolan Creek includes information on long-term flows and measurements of bacteria under varying flow conditions. For evaluating load reductions needed, part of the contributing load includes the permitted load from WWTFs, as well as estimates of the load associated with MS4 areas. For MS4 areas, loadings are generally based on the percent land area associated with the urbanized area defined within the 2010 Census data (e.g., TCEQ, 2012).

A goal of this data inventory report is to collect and summarize existing data needed for identifying sources and estimating loadings for Phase 3 of this project. Phase 2 of this project involves direct monitoring, which is addressing some data gaps previously identified through prior efforts in the watershed, but also will be used to aid in identifying sources. Phase 3 will then combine information from Phase 1 and 2 to estimate loadings within the watershed by source and sub-watershed using load duration curves and spatial modeling tools to complete the characterization of the watershed. Tables 1-2 and 1-3 provide a summary of the data needs for SELECT and for developing LDCs, which are a focus of this data inventory.

**Table 1-2** Summary of data needs for running SELECT.

Type of Data	Units	Use	Data Source
Spatial GIS data, Land use and cover	30-m resolution, 16 categories	Land use and cover categories for associating with bacteria loadings from various sources	Multi-Resolution Landuse Consortium National Land Cover Database
Spatial GIS data, Soils	Soil mapping units	Used in conjunction with the location of rural households to estimate risk of septic system failures	Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database
Location permitted discharge facilities, average monthly discharge	Location (latitude/longitude) & permitted average monthly discharge (MGD)	Used to define potential point sources of bacteria and nutrients	TCEQ Information Resources Division Central Registry or USEPA Enforcement & Compliance History Online (ECHO) website or directly from permitted facilities
Spatial GIS, Population data at various scales	Density down to blocks, as needed	Used to indicate population density in urban and rural areas	U.S. Census Bureau
Spatial GIS, Urbanized Areas	Spatial boundaries	Used to indicate municipal boundaries	U.S. Census Bureau
Spatial boundaries for counties and cities	Spatial boundaries	Used to indicate county boundaries and aid with city boundaries	Texas Natural Resources Information System (TNRIS) StratMap Boundaries with modifications, as provided, from municipalities
MS4 boundaries	Spatial boundaries	Used to indicate MS4 permit boundaries for urbanized areas	U.S. Census Bureau
Spatial GIS, point data	Household locations	Used to define rural population density with regard to septic systems and potential failure rates in conjunction with sewer service boundaries	U.S. Census Bureau
Spatial GIS, Stream layer	Line data	To define location of stream segments	National Hydrography Dataset (NHD)

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Type of Data	Units	Use	Data Source
Spatial data, livestock density	County level estimates adjusted to watershed area for major livestock groups	Used to estimate livestock density throughout the watershed	USDA Census of Agriculture
Spatial wildlife density	Deer density and other pertinent species, as available	Used to estimate deer density throughout the watershed	Texas Parks & Wildlife Department surveys and/or information from biologists
Spatial, pet density	Dog density per household	Used to estimate dog density throughout the watershed	American Veterinary Medical Association (2012) and stakeholder input
Spatial, feral hog density	Feral hog density	Used to estimate feral density throughout the watershed	TPWD, literature values and stakeholder input
Rates of fecal production	cfu/day	Used to estimate potential bacteria loads for various sources (i.e., feral hogs, deer, dogs, cattle or other livestock, and WWTF discharges)	EPA and literature values
Wastewater treatment facility (WWTF) discharges	Discharge rates and bacteria concentration data	Used to estimate bacteria loadings associated with WWTF discharges	TCEQ Information Resources Division Central Registry, USEPA Enforcement & Compliance History Online (ECHO), or directly from permitted facilities
Spatial, boundaries for sewer service areas	Spatial boundaries	Used to define areas on sewer based on sewer Certificates of Convenience and Necessity (CCNs) and municipal boundaries	Public Utility Commission of Texas & Municipal boundaries (TNRIS)
Spatial GIS data, Digital Elevation Models (DEMs)	30 meter resolution	Delineation of watershed and subwatershed boundaries	National Elevation Dataset from USGS

**Table 1-3** Summary of data needs for developing FDCs and LDCs.

Type of Data	Units	Use	Source
Time series, daily streamflow	Average daily (cfs)	Ranking of daily flow conditions for stream sites used for LDCs	United States Geological Survey (USGS) and direct project data
Concentration at various points in time	mg/L for nutrients and MPN/100mL or colonies/100mL for bacteria	Concentration of nitrates, orthophosphorus, total phosphorus and bacteria for LDCs.	TCEQ SWQMIS and direct project data
Instantaneous flow measurements collected with concentration data	cfs	Flow data to relate concentrations LDCs.	TCEQ SWQMIS and direct project data
Spatial data, location of existing SWQM stations	Latitude/longitude	Define location of stations within the watershed with existing water quality monitoring data in SWQMIS	TCEQ SWQM Clean Rivers Program
Spatial GIS data, Digital Elevation Models (DEMs)	30 meter resolution	Delineation of watershed and subwatershed boundaries	National Elevation Dataset from USGS
Wastewater treatment facility (WWTF) discharges	Permitted discharge rates	Used to estimate bacteria loadings associated with WWTF discharges	TCEQ Information Resources Division Central Registry, USEPA Enforcement & Compliance History Online (ECHO), or directly from permitted facilities
MS4 Areas	Percent land area above LDC sites	Used to estimate bacteria loadings associated with MS4 areas	U.S. Census Bureau urbanized areas

## SECTION 2

### Physical and Natural Features

#### General Watershed Description

Nolan Creek has two main forks, South Nolan Creek and North Nolan Creek, which converge about two miles northwest of the City of Belton (Figure 1-1). North Nolan Creek extends nearly 14 river miles through primarily range and forest land with the Fort Hood Military Reservation occupying large portions of its watershed area. South Nolan Creek flows about 20 river miles primarily in an eastward direction with its headwaters extending around the City of Killeen and including portions of the Fort Hood Military Reservation (Figure 1-1). After South Nolan Creek and North Nolan Creek merge, Nolan Creek continues for about 10 more river miles through the City of Belton prior to converging with the Leon River.

The Nolan Creek/South Nolan Creek watershed is located within the Cross Timbers ecoregion (Level III 29) as part of the Limestone Cut Plain (Level IV 29e; Griffith et al., 2007). The Limestone Cut Plain is known for its stair-step topography of mesas intertwined with broad valleys. Historically much of this area was grassland and woodland, but now it is largely urbanized, particularly along the western portion of South Nolan Creek. South Nolan Creek flows through cities of Killeen (2013 population estimate 136,438; Texas State Data Center, 2013), Harker Heights (27,960), and Nolanville (4,540). After South and North Nolan Creeks converge, Nolan Creek flows through the City of Belton (19,098) to merge with the Leon River.

#### Soils

According to the Bell County Soil Survey, soils within the watershed fall into two major associations; the Denton-Purves and the Speck-Tarrant-Purves (Huckabee et al., 1977). The majority of the watershed draining to South Nolan Creek is part of the Denton-Purves soil association, while the watershed draining to North Nolan Creek and most of Nolan Creek is part of the Speck-Tarrant-Purves association. The land area within the Denton-Purves association is nearly level to gently sloping. These soils are general silty clay extending about a foot to three feet thick resting over hard limestone bedrock. The Denton-Purves soils have a few areas that may be cultivated or provide improved pasture, but largely, if not urbanized, are used for livestock grazing. In urban areas, the shrink-swell potential of these soils can cause cracking and shifting of structures and corrosion of underground pipelines. Both the Denton and Purves soil series are noted to have severe limitations for septic tank absorption fields based on shallow depth to bedrock (8 to 40 inches) and the Denton series is noted for slow permeability.

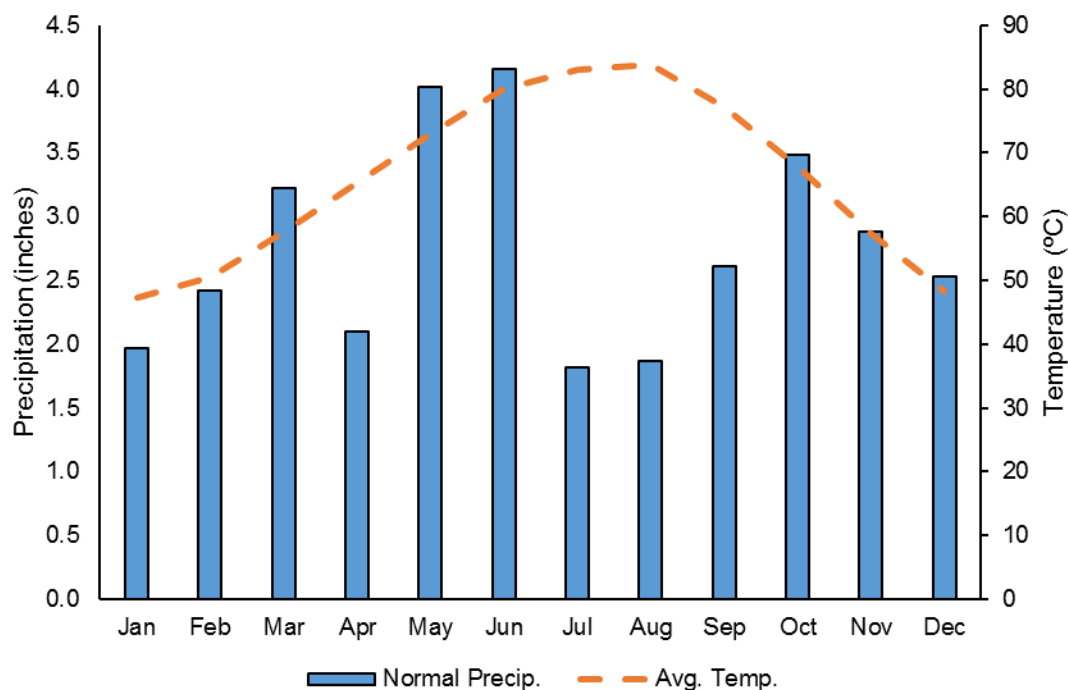
The Speck-Tarrant-Purves association is more undulating than the Denton-Purves association and represents shallow, gravelly clay loam or silty clay loam soils resting on limestone bedrock. This association primarily supports range and woodland used by livestock and as wildlife habitat. Small areas at the base of hills provide deeper loamy soils that may be cultivated. The woodland is considered noncommercial and due to encroachment of oak, juniper, and other plants described as a scrub forest by Huckabee et al. (1977). Features of this soil association that can affect urban developments are the shallow depth to bedrock and the shrink-swell potential in more clayey areas. Severe limitations are noted for septic tanks absorption fields for the three

major soil series in this association due to shallow depth to bedrock (8 to 20 inches) and slow permeability for the Speck soil series.

Soils data for the watershed were downloaded as county level geographic information system (GIS) data from the United States Department of Agriculture (USDA) – Natural Resources Conservation Service (NRCS) Geospatial Data Gateway website on September 17, 2014 (<http://datagateway.nrcs.usda.gov/GDGOrder.aspx>). The soils data are from the Soil Survey Geographic (SSURGO) database, which duplicates county level soil survey maps.

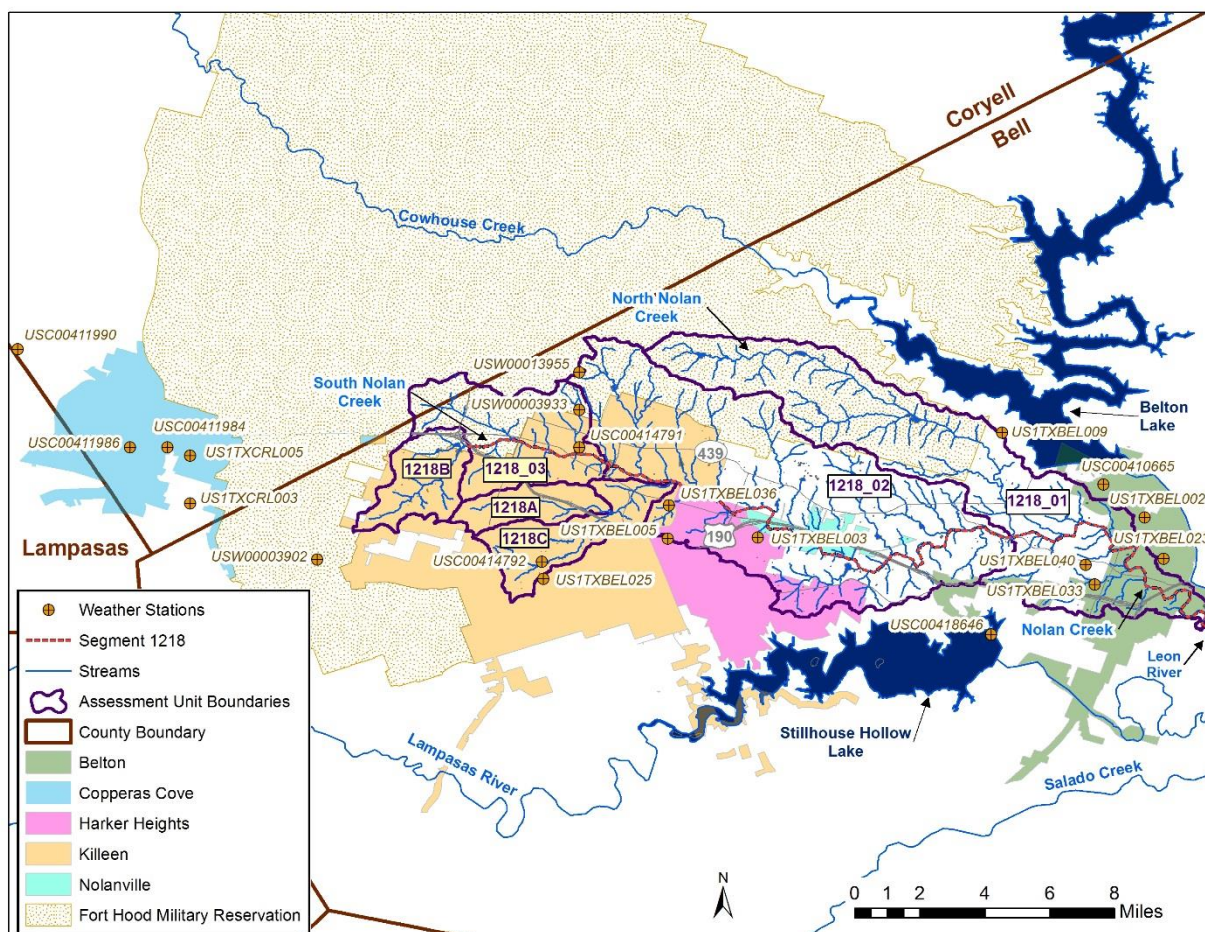
## Climate

The climate of the watershed is humid subtropical with hot summers and winters that are generally mild, although daily temperatures can be quite variable with Polar air surges often causing sudden drops (Orton, 1977). Precipitation based on 30-years of data from the National Weather Service for Killeen (1981-2010) averages 33.1 inches per year varying 1.8 to 4.2 inches per month (Figure 2-1). The wettest months are generally May and June with over 4 inches of precipitation on average and the driest months are July and August with less than 2 inches on average. Maximum average temperatures occur in July and August corresponding with the driest months of the year. The coolest months of the year are generally December and January. Snowfall is very unusual for the watershed area, but can occur on rare occasions. Freezing temperatures (below 32°F) generally as nighttime lows commonly occur between late November and early March. The prevailing winds are southerly with the strongest winds generally associated with spring thunderstorms (Orton, 1977).



**Figure 2-1** Monthly normal precipitation and average temperature for Killeen, Texas. Source: National Climate Data Center, monthly normal 1981-2010 (NCDC, 2014).

Precipitation records for locations within or near Nolan Creek watershed from the National Weather Service (NWS) were accessed via the National Climatic Data Center (NCDC) website (NCDC, 2014). While daily precipitation data were noted for 28 stations near or within the South Nolan Creek/Nolan Creek watershed, only a few stations had more than a few years of data with 95 percent completeness or better (Table 2-1, Figure 2-2). The three stations with the longest periods of record that are still currently reporting include Copperas Cove (USC0041984), Killeen (USC00414792 and USC00414791 combined), and Stillhouse Hollow Dam (USC00418646; Table 2-1). Currently active stations were located in conjunction with the communities of Copperas Cove, Kempner, Killeen, Harker Heights, and Belton (Table 2-1). Other active stations included those located on the Robert Gray Army Air Field, Fort Hood, Stillhouse Hollow Dam, and Belton Dam. In evaluating variation in annual precipitation for the watershed, a fairly good record from 1961 to 2013 could be established from daily data for Killeen (Figure 2-3). Of note, data from Copperas Cove or Stillhouse Hollow Dam were used to fill in when values were missing in the Killeen dataset. Recent annual values indicate well below normal precipitation in 2011 with near normal levels in 2012 (slightly below) and 2013 (slightly above).



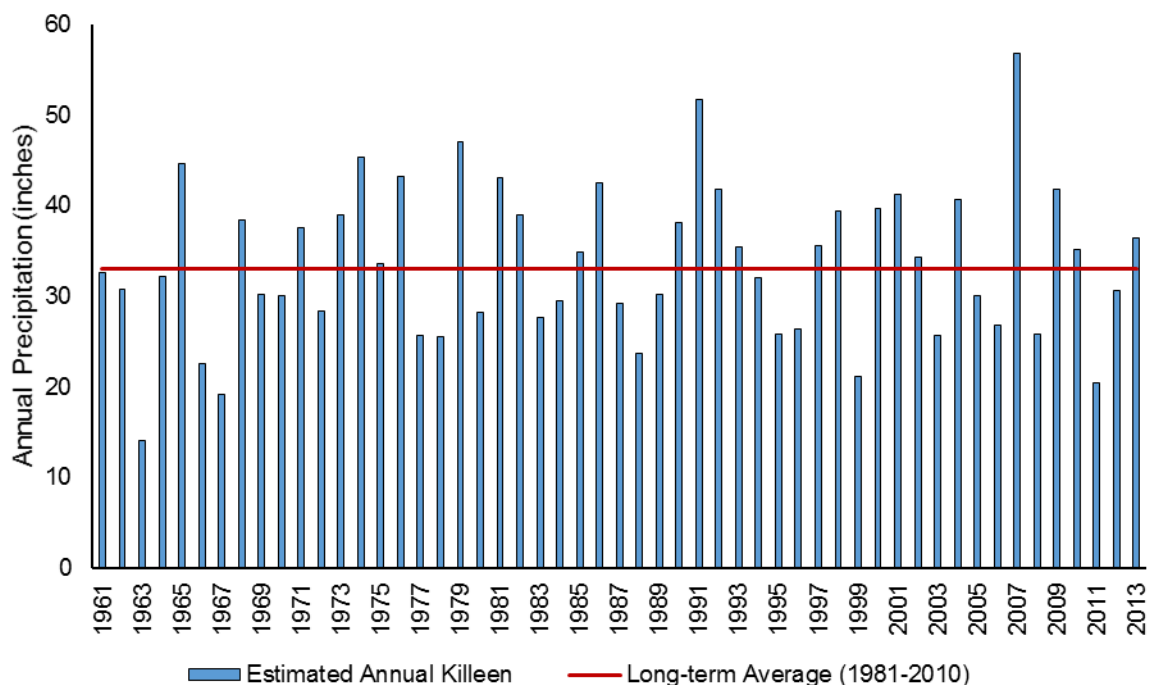
**Figure 2-2** Location of NWS stations with records of daily precipitation data within or near the Nolan Creek watershed. Source: NCDC (2014).

**Table 2-1** History of daily precipitation records for NWS stations within and surrounding the Nolan Creek watershed. Source: NCDC (2014), data downloaded October 10, 2014.

Station	Station Name	Latitude	Longitude	Start Date	End Date	Years with >95% Data Completeness <sup>b</sup>
GHCND:USC00411990	COPPERAS COVE 5 NW TX US	31.1602	-97.9667	1-Aug-1983	31-Aug-2014	28
GHCND:USC00411986	COPPERAS COVE TX US	31.1167	-97.9167	1-Feb-1966	31-Jan-1970	3
GHCND:USC00411984	COPPERAS COVE TX US	31.1167	-97.9000	1-Sep-1915	31-Jul-1983	55
GHCND:US1TXCRL005	COPPERAS COVE 0.8 ESE TX US <sup>a</sup>	31.1129	-97.8900	4-Mar-2013	Present	0
GHCND:US1TXCRL003	KEMPNER 6.7 ENE TX US	31.0916	-97.8900	1-Aug-2008	Present	5
GHCND:USW00003902	ROBERT GRAY ARMY AIR FIELD TX US	31.0667	-97.8333	26-Sep-1963	Present	12
GHCND:USC00414792	KILLEEN TX US	31.0658	-97.7333	1-Oct-1978	Present	16
GHCND:US1TXBEL025	KILLEEN 2.9 SSW TX US	31.0581	-97.7326	1-Aug-2010	Present	3
GHCND:USW00013955	KILLEEN FORT HOOD S ARMY AIR FIELD TX US	31.1500	-97.7167	1-Jan-1949	9-Apr-1952	0
GHCND:USC00414791	KILLEEN TX US	31.1167	-97.7167	1-Jan-1912	31-Aug-1978	18
GHCND:USW00003933	FORT HOOD TX US	31.1333	-97.7167	1-Nov-1960	Present	9
GHCND:US1TXBEL005	HARKER HEIGHTS 1.7 NW TX US	31.0760	-97.6773	11-Jun-2009	Present	1
GHCND:US1TXBEL036	KILLEEN 2.4 ESE TX US	31.0908	-97.6768	7-Nov-2013	20-Apr-2014	0
GHCND:US1TXBEL003	HARKER HEIGHTS 1.5 NE TX US	31.0765	-97.6371	24-Jul-2008	22-Nov-2009	0
GHCND:USC00418646	STILLHOUSE HOLLOW DAM TX US	31.0333	-97.5333	1-Jul-1963	Present	45
GHCND:US1TXBEL009	BELTON 5.4 NW TX US	31.1231	-97.5284	17-Jul-2009	Present	3
GHCND:US1TXBEL040	BELTON 1.6 W TX US	31.0643	-97.4912	20-May-2014	Present	0
GHCND:US1TXBEL033	BELTON 1.6 WSW TX US	31.0556	-97.4871	1-Apr-2014	9-Jun-2014	1
GHCND:USC00410665	BELTON DAM TX US	31.1000	-97.4833	1-Aug-1951	31-Dec-1992	38
GHCND:US1TXBEL002	BELTON 1.2 N TX US	31.0855	-97.4649	1-Apr-2008	18-Aug-2014	1
GHCND:US1TXBEL023	BELTON 0.4 E TX US	31.0670	-97.4564	21-Jun-2010	Present	0

a. Exact location unknown and estimated by NCDC.

b. Greater than 5% data completeness was indicated if more than 18 days within a year were noted as missing for precipitation data.



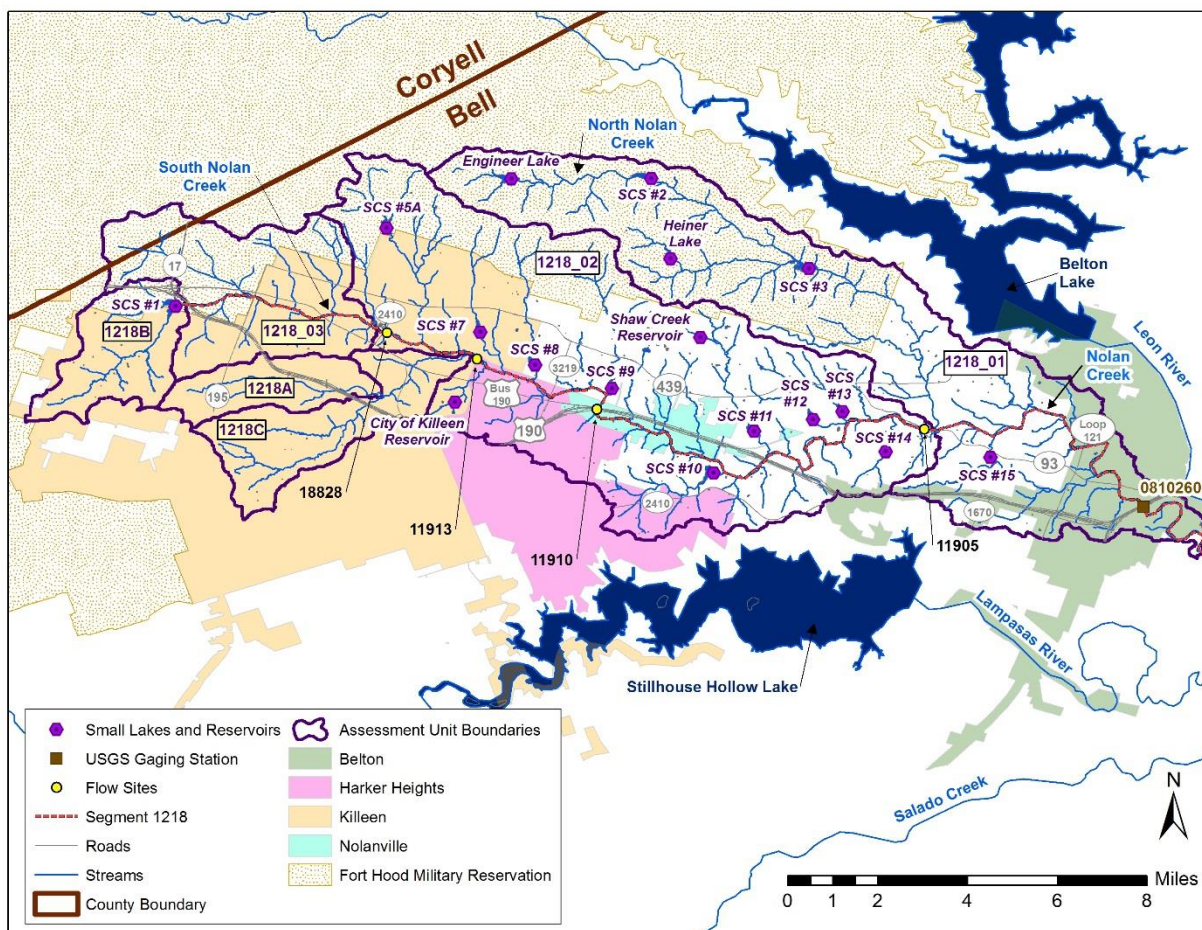
**Figure 2-3** Estimated annual precipitation for Killeen, Texas for 1961 through 2013. Missing values estimated using data from Copperas Cove or Stillhouse Hollow Lake Dam. Source: NCDC (2014).

## Hydrology

Hydrologic features include streams and reservoirs, but also topographic information used to delineate watershed boundaries as well as geologic information that aids in defining groundwater interactions and aquifers. To delineate the Nolan Creek/South Nolan Creek watershed boundaries, as shown in figures throughout this report, the stream network was used in combination with digital elevation models (DEMs). The stream network was obtained from the National Hydrology Dataset (NHD), which is managed by the USGS (<http://nhd.usgs.gov/index.html>). The NHD is a digital vector dataset that contains features such as lakes, ponds, stream, rivers, canals, dams, and stream gages. These data are designed for use in general mapping and analysis of surface-water systems. Digital elevation models with 30-meter resolution were downloaded from the USGS National Elevation Dataset (NED) using the National Map Viewer (<http://nationalmap.gov/viewer.html>). The overall watershed boundary, as well as sub-basins, were defined using the NED and NHD datasets with the delineation component of the ArcView Soil and Water Assessment Tool (AVSWAT-X, 2006).

With regard to daily streamflow and water level data, only one USGS gaging station has existed in the watershed (Figure 2-4; USGS, 2014a). Station 08102600 on Nolan Creek at Belton, Texas has a period of record for stream discharge from January 31, 1974 through November 3, 1982 (Figure 2-5). Median discharge for station 08102600 from 1974 through 1982 was 39 cfs. During this time period, the lowest average daily flow reported was 9 cfs and at least 50 percent of the time flows were 30 cfs or less (Figure 2-6). Only about 12 percent of the time were flows greater than 100 cfs exceeded and less than 1 percent of the time were flows greater than 1,000 cfs. In

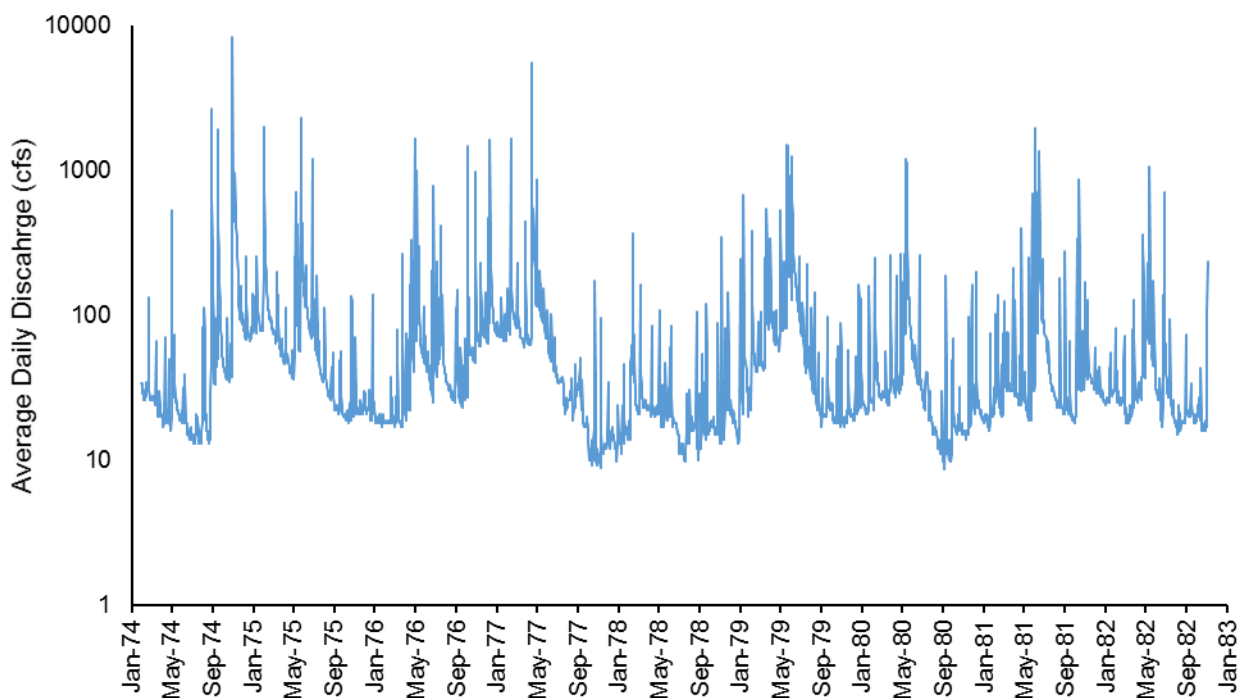
comparing long-term flow with precipitation data, the pattern of average monthly flows generally followed that of precipitation (see Figures 2-1 and 2-7). Of note, flow data represent an average over about 9 years rather than the 30 years for precipitation data, and these averages are for different time periods. Despite these differences between these two datasets, some seasonal patterns still persist. Similar to precipitation patterns, the highest average flows are noted in May and June and some of the lowest flows in the summer months of July and August.



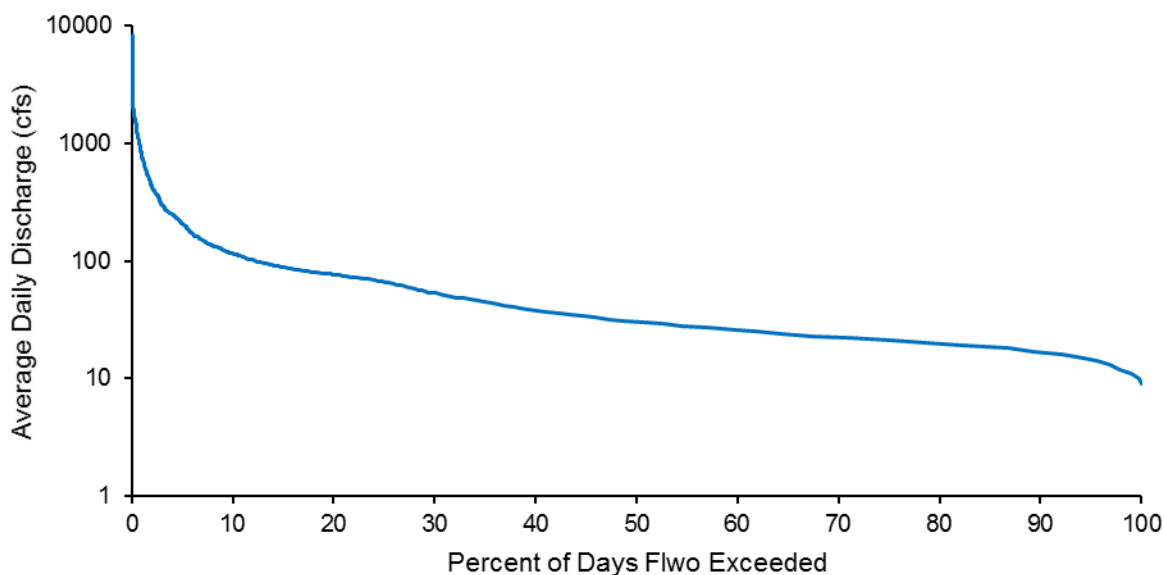
**Figure 2-4** Location of hydrologic features within the Nolan Creek/South Nolan Creek.

As part of Phase 2 within the current project, four flowmeters were installed at TCEQ stations 18828, 11913, 11910, and 11905 in July 2013 (Figure 2-4). Results from these flowmeters will be presented as part of an upcoming data collection and analysis report. The data from these four flowmeters will be used to aid in developing flow duration curves for these locations along the creek. These flowmeters are set to continuously monitor the stream stage at 5-minute increments. Of note, station 11913 was temporarily removed August 1, 2013 through October 10, 2013 due to construction work being done on the bridge on Roy Reynolds Road. Stream level data from these four locations appears to be highly correlated and may be used to fill in daily gaps, as necessary, to meet other project needs. Flow measurements are being taken when routine and storm monitoring occur, so stage-discharge relationships may be developed for these four stations.

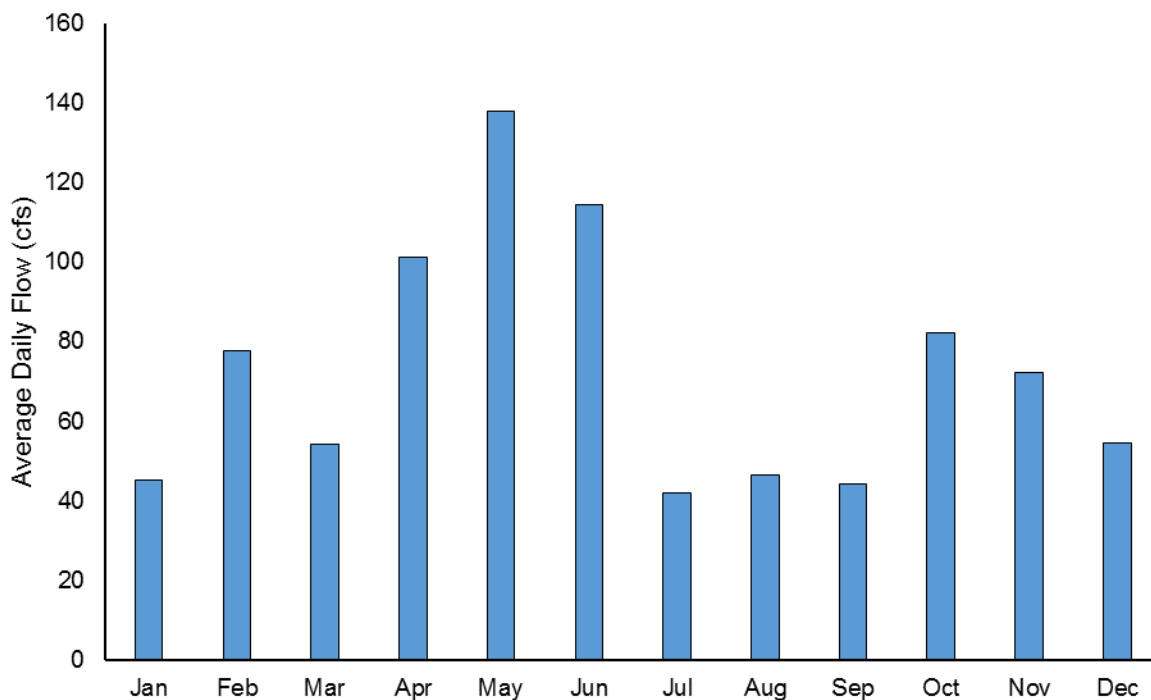
Other hydrologic features in the watershed include at least 17 small lakes and Soil Conservation Service (SCS) reservoirs (Figure 2-4).



**Figure 2-5** USGS daily data for station 08102600 on Nolan Creek at Belton, Texas. Source: USGS (2014a).



**Figure 2-6** Flow duration curve based on daily data from January 31, 1974 through November 3, 1982 for station 08102600 on Nolan Creek at Belton, Texas. Source: USGS (2014a).



**Figure 2-7** USGS average monthly data (1974-1981) for station 08102600 on Nolan Creek at Belton, Texas. Source: USGS (2014a).

With regard to groundwater, the Nolan Creek/South Nolan Creek watershed overlays the Trinity (subcrop) aquifer (George et al., 2011). The majority of the watershed area (99 percent) lies within Bell County, which comprises the Clearwater Underground Water Conservation District. A very small portion of the watershed lies within Coryell County, which is part of the Middle Trinity Groundwater Conservation District. The Texas Water Development Board in cooperation with the Clearwater Underground Water Conservation District maintains three monitoring wells in Bell County that reach down into the Trinity Aquifer. Of these three wells, only one (State Well 4058201) just barely resides within the most western portion of the South Nolan Creek watershed. Drinking water for the municipalities within the watershed comes from Lake Belton as surface water. While some private residences use groundwater as drinking water, well depths into the Trinity Aquifer in this area are often over 500 ft deep.

Baseflow along Little Nolan Creek and the headwaters of South Nolan Creek is associated with shallow groundwater discharge that often occurs year-round. Seeps and small springs are common where shallow soils overlie limestone that has weathered leading to karst bedrock. There are no permitted discharges within the sub-watershed of Little Nolan Creek nor within the headwaters of South Nolan Creek. As discussed later in Section 4, several permitted point source outfalls occur further along Nolan Creek/South Nolan Creek providing discharge that supplements groundwater baseflow contributions.

## SECTION 3

### Population Characteristics and Land Use

#### Population Characteristics

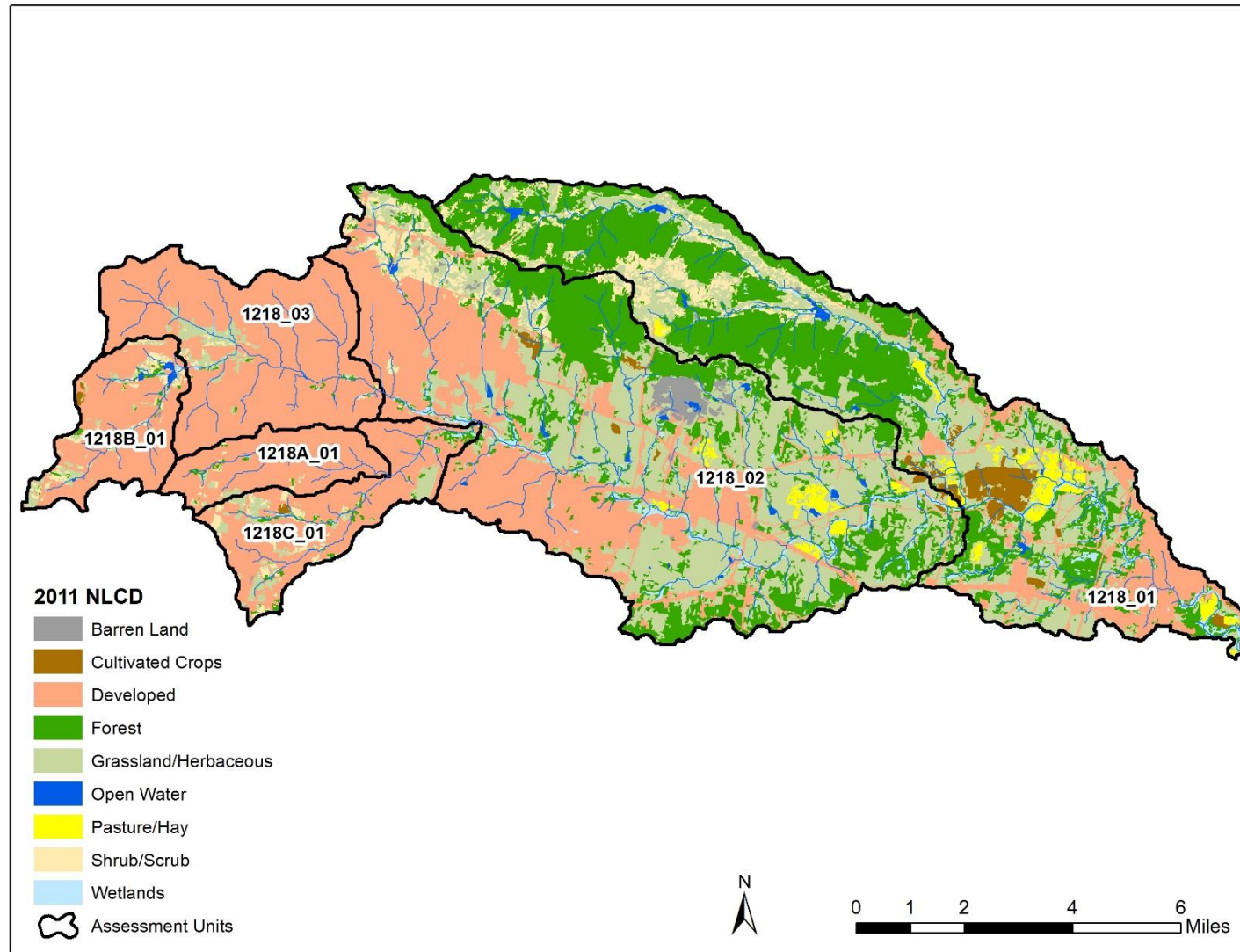
The major population centers as noted earlier are the cities of Killeen (2013 population estimate 136,438; Texas State Data Center, 2013), Harker Heights (27,960), and Nolanville (4,540) along South Nolan Creek and the City of Belton (19,098) along Nolan Creek. The Fort Hood Military Reservation also has a large fluctuating population and provides some base housing for military families with about 7,000 units near or within the Nolan Creek/South Nolan Creek watershed.

#### Land Use

While situated primarily within Bell County, the land use of the Nolan Creek/South Nolan Creek watershed varies greatly from the county with a much larger portion of the watershed associated with urban development (Table 3-1). These differences in land use between the county and the watershed are important, as county level data are often used in SELECT for estimating source densities, specifically for livestock, which will need adjustment based on the land categories used by livestock. This is discussed further in Section 4. While the density of development does vary, almost the entire western third of the watershed is considered developed at some level (Figure 3-1).

**Table 3-1** Comparison of land use/land cover for the Nolan Creek/South Nolan Creek watershed with Bell County. Source: 2011 National Land Cover Database (USGS, 2014b).

Category	Nolan Creek/South Nolan Creek Watershed (%)	Nolan Creek/South Nolan Creek Watershed (acres)	Bell County (%)	Bell County (acres)
Developed	40.1	29,196	13.3	92,480
Barren	0.8	590	0.3	2,086
Forest	22.6	16,708	17.5	121,684
Shrub/Scrub	4.2	3,040	4.3	29,899
Grassland Herbaceous	26.8	19,517	32.0	222,508
Pasture Hay	1.5	1,072	7.5	52,150
Cultivated Crops	1.4	991	19.0	132,114
Wetlands	1.8	1,337	2.9	20,165
Open Water	0.5	360	3.2	22,251
Totals	100.0	72,811	100.0	695,336



**Figure 3-1** Land use/land cover for the Nolan Creek/South Nolan Creek watershed. Source: 2011 National Land Cover Database (USGS, 2014b).

Land use/land cover data were obtained from the 2011 National Land Cover Database. The 2011 National Land Cover Database applies a 30 meter spatial resolution and is based on circa 2011 Landsat satellite data (USGS, 2014b). The land use classification descriptions from the National Land Cover Database representing the watershed area are defined as follows:

**Open Water** – areas of open water, generally with less than 25% cover of vegetation or soil.

**Developed** – areas with a mixture of some constructed materials and vegetation with impervious surfaces ranging from 20% to 100% of the total area. Subcategories of developed, which were combined in Table 3-1 and Figure 3-1, include:

- Developed, Open Space – areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
- Developed, Low Intensity – areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.
- Developed, Medium Intensity – areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
- Developed High Intensity – highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.

**Barren Land** – areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

**Forest** – areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Subcategories of forest, which were combined in Table 3-1 and Figure 3-1, include:

- Deciduous Forest – areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
- Evergreen Forest – areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.

- **Mixed Forest** – areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.

**Shrub/Scrub** – areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

**Grassland/Herbaceous** – areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

**Pasture/Hay** – areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.

**Cultivated Crops** – areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

**Wetlands** – areas where the soil or substrate is periodically saturated with or covered with water. Subcategories, which were combined in Table 3-1 and Figure 3-1, include:

- **Woody Wetlands** – areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
- **Emergent Herbaceous Wetlands** – Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Because developed land is one of the dominate land use categories and the intensity of use can vary greatly, this category is also presented by subcategory within AUs (Figure 3-2). In breaking out the watershed land area by water quality AU, AU 1218\_02 represents the majority of the area (Table 3-2). The land use/land cover associated with each AU varies greatly with developed land covering more than 75 percent of the land area in AUs 1218\_03, 1218A, 1218B, and 1218C (Table 3-3). In AU 1218\_02, developed land is still prominent covering about a third of the land area, but grassland/herbaceous and forest combined represent over half the land area. While less than 2 percent of the area within AU 1218\_02, much of the barren land is aggregated within the central portion of the watershed representing a limestone quarry just north of the City of Nolanville (Figure 3-1). In AU 1218\_01, forest is even more dominant, particularly along the watershed area of North Nolan Creek with grassland/herbaceous and developed areas still representing prominent land use/land covers.

By subcategory for developed land (Table 3-4), open space represented most of the developed land in AU 1218\_01. Inspection of several of these open space developed areas within AU

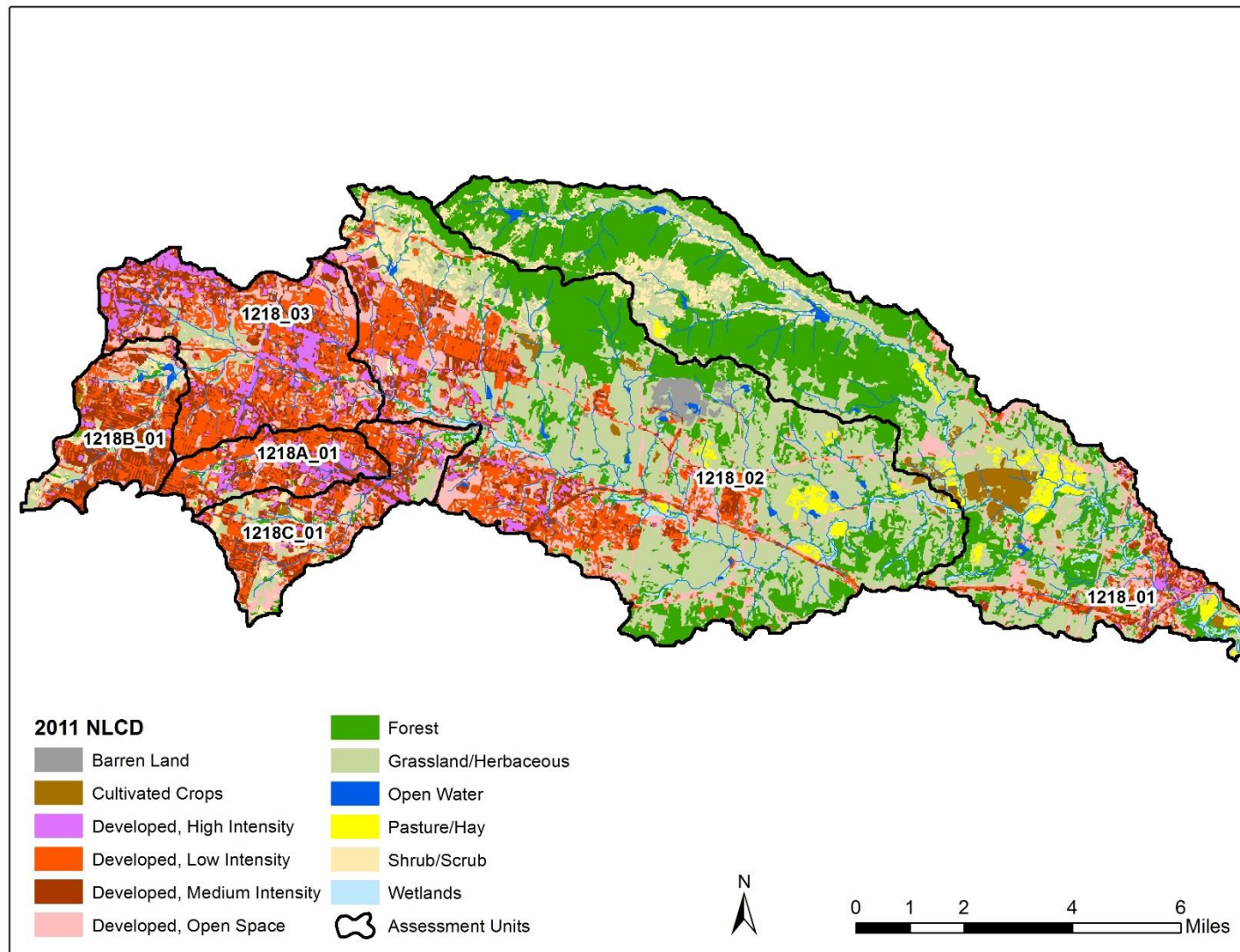
1218\_01 using Google maps indicated a few large rural subdivisions outside the City of Belton and several parks and large-lot subdivisions within Belton. The high intensity developed area within AU 1218\_01 largely corresponded with the downtown area of Belton off Central and E 2<sup>nd</sup> Ave between N Pear St and Blair St, which has many large buildings with large paved areas for parking lots. Within AU 1218\_02, there were similar findings with shopping areas in Harker Heights and Killeen representing high intensity developed areas as well as the air field on Fort Hood. Open areas corresponded with a golf course, parks, and areas with only a few buildings and very limited paved area. Within AU 1218\_03, the downtown area of Killeen as represented between N. College and 10<sup>th</sup> St and Rancier Ave and W. Veterans Memorial Blvd as well as shopping areas on S. Fort Hood St were high intensity developed areas. Paved areas within Fort Hood were also noted as high intensity developed. In general, the medium to low intensity developed areas throughout the watershed appeared to correspond with housing density.

**Table 3-2** Land area associated with each AU within the Nolan Creek/South Nolan Creek watershed.

<b>AU</b>	<b>Acres</b>	<b>Percent</b>
1218_01	23,317	32%
1218_02	30,902	42%
1218_03	7,998	11%
1218A	2,579	4%
1218B	3,589	5%
1218C	4,428	6%
Total	72,811	100%

**Table 3-3** Land use/land cover associated with each AU within the Nolan Creek/South Nolan Creek watershed. Source: 2011 National Land Cover Database (USGS, 2014b).

<b>Land Use/Land Cover Category</b>	<b>1218_01</b>	<b>1218_02</b>	<b>1218_03</b>	<b>1218A</b>	<b>1218B</b>	<b>1218C</b>
Barren Land	0.1%	1.8%	0.0%	0.0%	0.1%	0.3%
Cultivated Crops	3.3%	0.5%	0.0%	0.0%	0.7%	0.5%
Developed	13.3%	32.1%	93.6%	94.2%	79.9%	76.6%
Forest	41.9%	21.4%	0.4%	1.3%	1.9%	4.2%
Grassland/Herbaceous	29.3%	36.8%	5.0%	2.5%	8.2%	12.0%
Open Water	0.6%	0.5%	0.0%	0.0%	1.2%	0.0%
Pasture/Hay	2.9%	1.3%	0.0%	0.0%	0.0%	0.0%
Shrub/Scrub	5.9%	3.3%	0.8%	1.9%	7.7%	5.9%
Wetlands	2.6%	2.2%	0.1%	0.1%	0.3%	0.5%



**Figure 3-2** Land use/land cover for the Nolan Creek/South Nolan Creek watershed showing developed subcategories. Source: 2011 National Land Cover Database (USGS, 2014b).

**Table 3-4** Percent developed land by subcategory and number of total acres of developed land within each AU of the Nolan Creek/South Nolan Creek watershed. Source: 2011 National Land Cover Database (USGS, 2014b).

<b>Developed Subcategory</b>	<b>1218_01</b>	<b>1218_02</b>	<b>1218_03</b>	<b>1218A</b>	<b>1218B</b>	<b>1218C</b>
Developed, High Intensity	6%	6%	17%	18%	4%	8%
Developed, Medium Intensity	18%	18%	24%	30%	43%	32%
Developed, Low Intensity	19%	37%	36%	37%	34%	30%
Developed, Open Space	57%	39%	22%	15%	20%	30%
<b>Total Acres Developed</b>	<b>3,106</b>	<b>9,913</b>	<b>7,488</b>	<b>2,430</b>	<b>2,867</b>	<b>3,391</b>

## SECTION 4

### Potential Pollutant Sources

#### Regulated Sources

Potential sources of bacteria and other sources of pollution can be divided into two general categories: regulated and non-regulated. Pollution sources that are regulated have permits issued by TCEQ under the Texas Pollutant Discharge Elimination System (TPDES) as part of the National Pollutant Discharge Elimination System (NPDES) under EPA. Examples of regulated point sources include wastewater treatment facility (WWTF) discharges, stormwater discharges associated with municipal separate storm sewer systems (MS4s), and concentrated animal feeding operations (CAFOs). These various regulated sources are required to have either an individual permit that is facility specific or operate under a general permit.

#### *Wastewater Permits*

There are eight permitted outfalls that discharge within the Nolan Creek/South Nolan Creek watershed (Table 4-1, Figure 4-1). Of note, the Bell County Water Control and Improvement District (WCID) No. 1 - Plant 3 facility, also known as the “South Plant”, is physically located south of the watershed on 8290 Chaparral Road in Killeen, but discharges to South Nolan Creek within the City of Nolanville. Managers at the WCID No. 1 - Plant 3 have indicated that if approved as part of an upcoming permit renewal, portions of the wastewater from this plant may be discharged to Trimmier Creek, outside the Nolan Creek/South Nolan Creek watershed, but emphasized that this potential change as of April 2015 has not yet been approved. Bell County WCID No. 1 also runs a composting facility, which is located outside the watershed boundary, but processes biosolids from all three of its WWTFs.

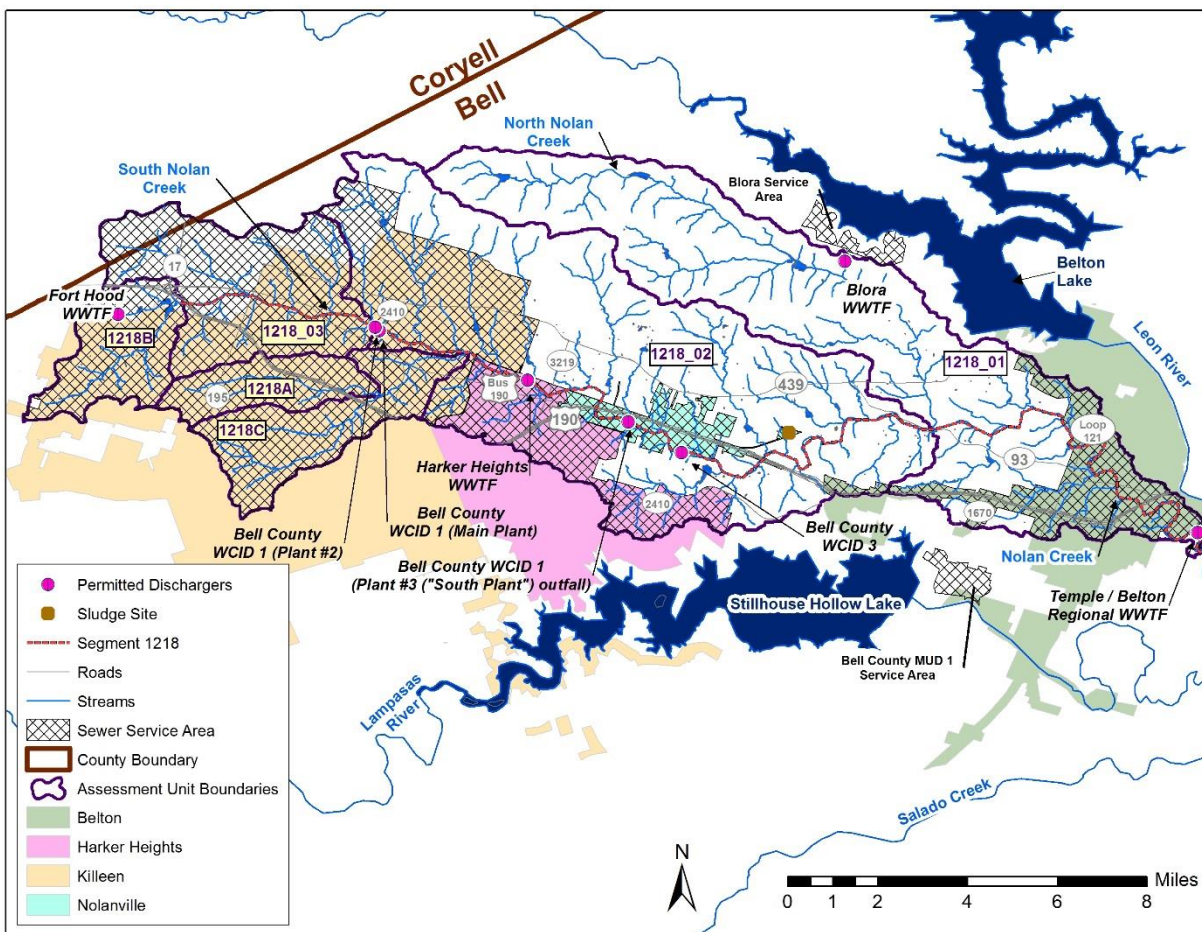
The service areas for these WWTFs were defined using the Certificates of Convenience and Necessity (CCN) boundaries for sewer obtained from Public Utility Commission of Texas (<https://www.puc.texas.gov/industry/water/utilities/gis.aspx>), supplemented with municipal boundaries, as not all current service areas were defined within the available CCN sewer layer (Figure 4-2). Of note, the service areas for some of these dischargers extends beyond the watershed boundary. This extended service area largely follows the municipal boundaries for the cities of Killeen and Harker Heights.

In association with the sewer lines that pipe untreated sewage to WWTFs, unauthorized discharges or sanitary sewer overflows (SSOs) can occur when pipes overflow through a manhole, cleanout, or broken pipe. Water Quality Noncompliance Notifications to TCEQ (see Appendix A) and news reports note SSOs have occurred on occasion and continue to occur throughout the watershed, but in more recent years, these SSOs are generally contained and raw sewage cleaned up with vacuum trucks to limit its impact on waterways (Ramirez, 2014).

**Table 4-1** Permitted WWTF within the Nolan Creek/South Nolan Creek watershed Source: Central Registry TCEQ (2014b).

Facility Name	Facility Location	Latitude	Longitude	EPA ID	Permit #	Permitted Discharge (MGD)
Temple Belton Regional WWTF	Belton, TX	31.0432930	-97.4386970	TX0058378	WQ0011318001	10
Bell County WCID No. 3 WWTF	Nolanville, TX	31.0690260	-97.6050450	TX0069191	WQ0010797001	0.675
City of Harker Heights WWTF	Harker Heights, TX	31.0923330	-97.6546730	TX0024473	WQ0010155001	3
Bell County WCID No. 1 WWTF (Main Plant)	Killeen, TX	31.1082780	-97.7025070	TX0024597	WQ0010351002	18
Bell County WCID No. 1 (Plant 2)	Killeen, TX	31.1093070	-97.7037850	TX0102938	WQ0010351003	6
Bell County WCID No. 1 (Plant 3, South Plant)	Killeen, TX	31.0788370	-97.622790	TX0125377	WQ0014387001	6
Universal Services Ft Hood WWTF	Ft Hood, TX	31.1135080	-97.7866860	TX0101869	WQ0013358001	0.09
Blora WWTF	Ft Hood, TX	31.1305167	-97.5523898	TX0132446	WQ0014994001	0.03

Drainage of raw sewage due to SSOs has been indicated as a past problem along South Nolan Creek based on information from stakeholders. The following examples indicate some of the issues with sewer lines and wastewater treatment systems that could impact water quality within Nolan Creek/South Nolan Creek. A sewage spill in February 2011 of almost 300,000 gallons resulted in a fish kill investigated by Texas Parks and Wildlife Department (TPWD) (Scott, 2011). A SSO occurred in Harker Heights in September 2010 after two days of extreme flooding associated with Tropical Storm Hermine leading to about 430,000 gallons of raw sewage spilling into South Nolan Creek (KXXV-TX News, 2010). While not resulting in a spill, stormwater from an October 2013 event transported an oak tree that cracked a concrete block encasing an aerial sewer line running over the creek within the City of Nolanville (Lynch, 2013). As of January 2014, this damaged sewer line was still not leaking but was considered a “ticking time bomb” as funding efforts for replacement were being pursued (Griffin, 2014).



**Figure 4-1** Location of WWTF discharges and service area for wastewater collection based on CCN and municipal boundaries within the Nolan Creek/South Nolan Creek watershed. Note: The service area for some of these dischargers extends outside the watershed boundaries, largely following municipal boundaries for the cities of Killeen and Harker Heights. Location of WWTF discharges obtained from TCEQ GIS layer of permitted wastewater outfalls, publication date March 12, 2014

In 2009, a breakdown of the WWTF occurred at WCID No. 1, Plant 3 due to high levels of grease, fats, and oils leading to the need for new diffusors (Chen, 2010). As a result of these high grease levels at the WCID No. 1 - Plant 3, the City of Killeen passed an ordinance that regulates fats, oils, and grease entering the city's sewer system (Killeen, Texas Code of Ordinances Part II, Article III Sewers and Sewage Disposal, Division 3. Fat, Oil and Grease Control and Prevention) and recently revised this ordinance decreasing water temperatures for local food service from 150°F to 120°F to better allow trapping of grease, thus, better protecting the sewage collection system and treatment plants from damage (Stewart, 2014). Such ordinances and enforcement of them is an important part of controlling SSOs, which not only release bacteria into the water, but can also cause fish kills.

An Open Records Request (ORR) to TCEQ regarding unauthorized discharges for the last 10 years provided some information on the frequency and location of SSOs (Appendix A). A review

of these data indicate a fairly large number of spills associated with the cities of Harker Heights and Killeen. While data were requested back to 2004, most information provided for SSO events between 2004 and 2012 did not give specific locations. A large portion of these spills appeared to be related to grease and paper towels blocking service lines causing raw waste to overflow from manholes. Grease clogging of sewer lines is considered an on-going problem in dealing with wastewater within the watershed (Janes, 2013) and is something addressed in the MS4 permits of each community. In evaluating the ORR information for 2013 and 2014, 71 separate SSO events were noted. Most of these events were relatively small (< 200 gallons), and according to municipalities, these SSO events were cleaned and sanitized to mitigate the effect of the spill. The impact on stream water quality with regard to bacteria should, thus, be limited, particularly when smaller, dry-weather SSO events occur.

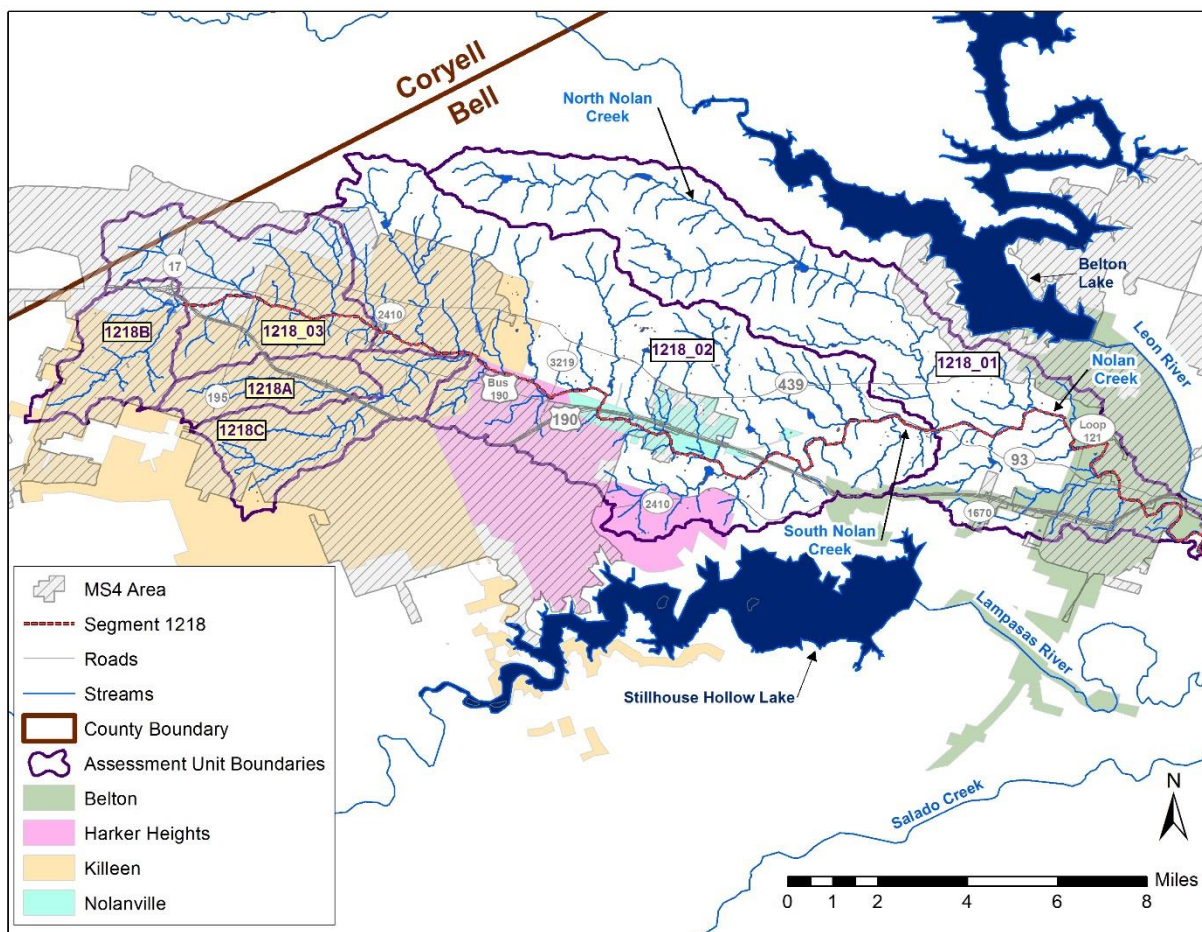
To evaluate the potential impact of SSOs on stream water quality, an effort will be made to compare the timing and location of SSO events with when water quality samples were collected for various sites to see if a relationship emerges. Precipitation records are being used to classify each SSO event as a “dry” or “wet”, as wet-weather events are more likely to impact stream water quality. Fish kill data obtained from an ORR made to Texas Parks and Wildlife Department (TPWD) will also be used to supplement SSO data (Appendix B). Between 1972 and 2014, 37 fish kills were reported, 13 of which raw sewage was suspected as the cause. In 2013 and 2014, eight fish kills were reported, four of which were related to sewage releases. Because direct monitoring for the project continues through June 2015, a follow-up ORR will be needed of both TCEQ and TPWD of SSO and fish kill information for comparison with stream water quality data.

### ***Regulated Stormwater***

The TPDES and the NPDES MS4 Phase I and II rules require municipalities and certain other entities in urban areas to obtain permits for their stormwater systems. Phase I permits are individual permits for large and medium sized communities with populations of or exceeding 100,000 (based on 1990 U.S. Census data), whereas Phase II permits are for smaller communities that are located within an “Urbanized Area”. An “Urbanized Area” is defined by the U.S. Census Bureau as an area with populations greater than 50,000 and with an overall population density of at least 1,000 people per square mile. Within the watershed area the following six entities have Phase II MS4 permits:

- Bell County – TXR040055
- Killeen – TXR040010
- Harker Heights – TXR040011
- Belton – TXR040351
- Fort Hood Family Housing LP – TXR040317
- Nolanville – TXR040175

For Phase II permits the jurisdictional area is defined as the intersection or overlapping areas of the city limits and the 2000 or 2010 Census Urbanized Areas (Figure 4-2). For Bell County and Fort Hood, MS4 areas includes urbanized areas not associated with municipalities.



**Figure 4-2** Location of MS4 areas within the Nolan Creek/South Nolan Creek watershed.  
Source: 2010 Census Data of urbanized areas.

All six fall under the Phase II MS4 requirements and are permitted under the small MS4 TPDES General Permit (TXR040000) effective August 13, 2007. Of the six, Bell County and Fort Hood are considered non-traditional small MS4s in that these entities cannot pass ordinances nor have the enforcement capability of traditional small MS4s associated with cities. While the 2007 MS4 General Permit was issued for only five years and expired on August 12, 2012, a notice of intent to renew this general permit was published in the Texas Register on April 13, 2012, which allowed administrative continuance of coverage under the 2007 Small MS4 General Permit until issuance of a new general permit. On December 13, 2013, a new small MS4 General Permit was issued, at which time all regulated entities were given 180 days to apply for coverage or a waiver under this new general permit, thus, authorization status under the 2007 Small MS4 General Permit ended June 11, 2014. According to TCEQ on-line permit records as of November 3, 2014, all six regulated entities in the Nolan Creek/South Nolan Creek watershed, except Nolanville, had submitted a notice-of-intent to renew coverage under the new 2013 Small MS4 General Permit with a status of “pending”. It is anticipated that these six regulated entities will have approved permits in the coming months and until so continue to function under the 2007 Small MS4 General Permit.

While control measures are outlined in the stormwater management plans associated with each MS4 permit, currently very limited data are available indicating the impact of these MS4 areas on stream water quality. Under Phase 2 of this project, water quality monitoring is occurring at 11 stations throughout the watershed, and the percentage land area above sampling stations associated with MS4 areas will be calculated and used to estimate the impact of these areas on bacteria concentrations.

### ***CAFOs and Other Permitted Facilities***

There are no permitted concentrated animal feeding operations (CAFOs) within the Nolan Creek/South Nolan Creek watershed.

There is an active permit (WQ000445800) for the beneficial land application of sewage sludge and domestic septage for the Grandy Ranch located about 1.2 miles east of the intersection of U.S. Highway 190 and Paddy Hamilton Road (see Figure 4-1). The permit covers land application site of about 368 acres with an application rate not to exceed 2.61 dry tons per acre per year of sewage sludge and 3,692.3 gallons per acre per year domestic septage.

### **Non-Regulated Sources**

Non-regulated are not regulated by permit under the TPDES. Non-regulated sources of bacteria include waste from livestock, wildlife, pets, and failing on-site sewage facilities (OSSFs).

### ***Livestock***

While no CAFOs exist in the watershed, livestock are present in the rural areas. Even within Fort Hood, grazing is allowed in some locations. Specific watershed level information regarding the number of grazing livestock is unavailable, but county level statistics are available for the United States Department of Agriculture (USDA). The latest USDA Census of Agriculture conducted by the National Agriculture Statistics Service (NASS) in 2012 notes cattle followed by goats and sheep as the dominant livestock types for Bell County (USDA-NASS, 2014). Horses and ponies combined with estimates of mules, burros, and donkeys are also prominent livestock categories (Table 4-2). Poultry, while noted as a major livestock category within Bell County with almost 14,000 chickens, primarily layers, was excluded as a category for the Nolan Creek/South Nolan Creek watershed, because no poultry houses are located within the watershed area. Hogs and pigs were also excluded as there are no large hog facilities within the watershed.

Because the land use for Bell County as a whole is quite different from the land use within the Nolan Creek/South Nolan Creek watershed (see Table 3-1), livestock numbers for Bell County were related to the land covers most often associated with each type of livestock (Table 4-3). For example, cattle and calves were assumed to be distributed within Bell County on land classified as grassland herbaceous and pasture hay. To determine an estimate of the number of cattle and calves within the Nolan Creek/South Nolan Creek watershed, a weighted average was determined by multiplying the number of cattle and calves in Bell County (34,922) by the ratio of land within the watershed associated with grassland herbaceous and pasture hay to the amount in Bell County (20,589 acres /274,658 acres).

**Table 4-2** Livestock census estimates for Bell County. Source: USDA-NASS (2014).

Category	Bell County Total Inventory Number
Cattle & Calves	34,922
All Poultry	13,898
All Goats	12,813
Sheep & Lambs	4,269
Horses & Ponies	2,903
Mules, Burros, & Donkeys	832
Hogs & Pigs	750

**Table 4-3** Livestock estimates for the Nolan Creek/South Nolan Creek watershed. Based on 2012 Census of Agriculture for Bell County (USDA-NASS, 2014) and 2011 NLCD (USGS, 2014b).

Category	Estimated Animals in Bell County	Associated Land Use/Land Cover (LULC)	Land Area in Bell County represented by LULC (acres)	Land Area in Nolan Creek/South Nolan Creek Watershed associated with LULC (acres)	Estimated Animals in Nolan Creek/South Nolan Creek Watershed
Cattle & Calves	34,922	Grassland Herbaceous & Pasture Hay	274,658	20,589	2,618
Sheep & Goats	17,082	Grassland Herbaceous, Pasture Hay, Shrubland & Forest	396,342	37,297	1,607
Horses & Ponies and Mules, Burros, & Donkeys	3,735	Grassland Herbaceous & Pasture Hay	274,658	20,589	280

### ***Domestic Animals***

Bacteria sources that wash off the land from developed land areas are generally associated with pet wastes, primarily dogs, as cats, unless in feral colonies, are generally considered house animals. The American Veterinarian Medical Association (AVMA) estimates about 0.6 dogs per household throughout the U.S. and about 0.8 dogs per household in Texas (AVMA, 2012).

### ***Wildlife and Feral Animals***

While smaller wildlife, such as raccoons and opossums that have adapted to rural and urban settings, deer are more likely found in the range and woodland areas (Figure 3-1). The Speck-Tarrant-Purves soil association found largely along North Nolan Creek and Nolan Creek supports range and woodland and is noted in the Bell County Soil Survey as good wildlife habitat (Huckabee et al., 1977). According to Texas Parks and Wildlife Department (TPWD, 2012), the Nolan Creek/South Nolan Creek watershed falls into Resource Management Unit 23 of the Cross Timbers ecoregion and survey estimates as of 2011 indicate about 81 deer/1,000 acres or 12.3 acres per deer for this ecoregion where appropriate habitat occurs.

Feral hogs, while not natural wildlife, are invasive, unmanaged animals that are found throughout Texas and can contribute bacteria to streams in a manner similar to native wildlife. Feral hogs are classified by TPWD as unprotected, exotic, non-game animals. Feral hogs are noted for moving in groups along waterways. Particularly in times of drought, feral hogs will congregate near perennial water sources to drink and wallow (Taylor, 2003). While not typically found in urban areas, in rural areas of Texas hog densities have been estimated to range from 25 to 54 acres per hog (Borel et al., 2012).

### ***Cropland***

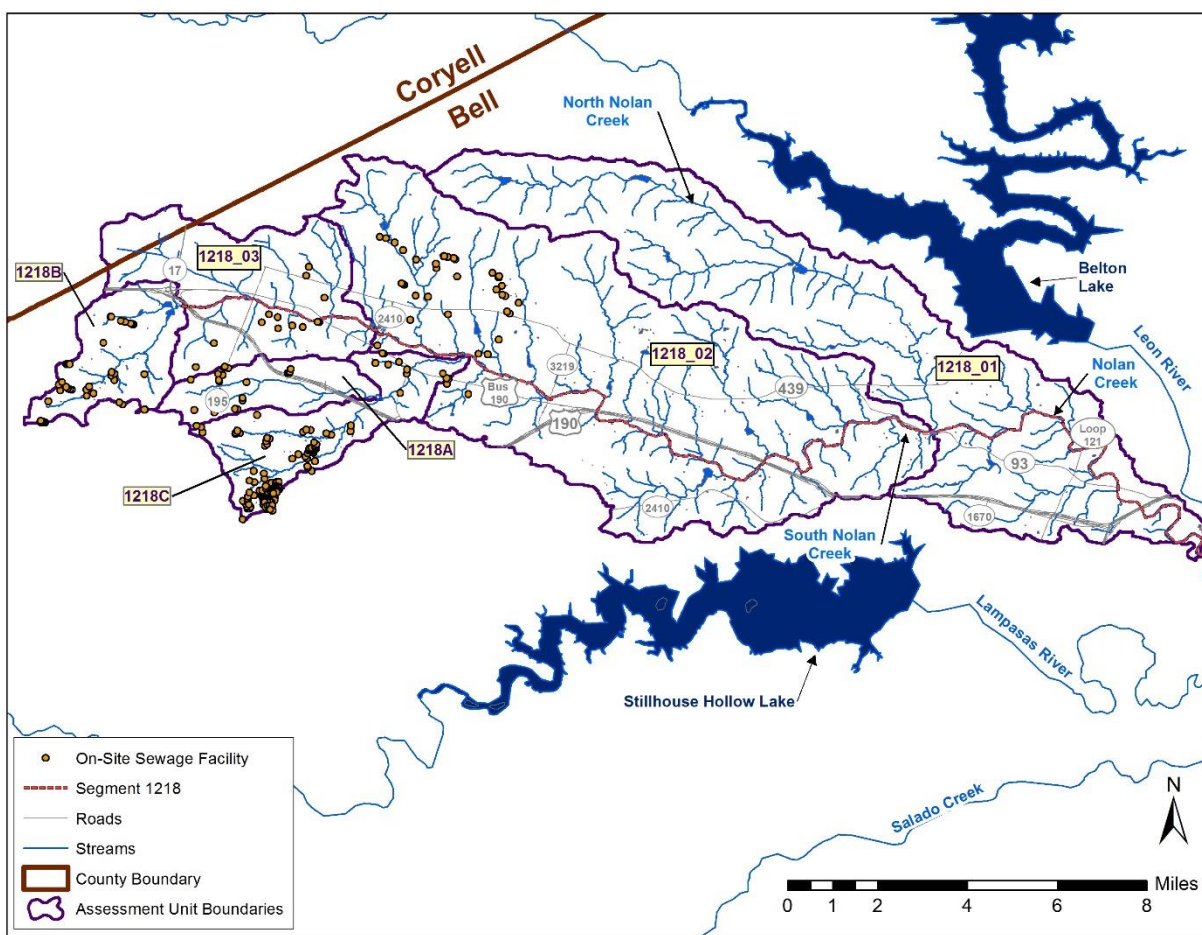
While cropland is not generally considered a source of bacteria unless organic fertilizer is applied, it is often considered a source of nutrients in runoff from fertilizer whether organic or inorganic. Within the Nolan Creek/South Nolan Creek watershed, soil survey information indicates that there is limited land suitable for cropland (Huckabee et al., 1977). The land use/land cover layer supports this assertion indicating only 1.4 percent of the watershed as cropland with the majority of the cropland area laying just to the east within the Nolan Creek watershed past the convergence of South Nolan Creek with North Nolan Creek (Figure 3-1). Cultivated crops in this area are primarily oats, winter wheat, and corn.

Improved pasture used for hay or grazing may also receive fertilizer, thus being a potential source of nutrients in runoff and bacteria if manure is applied as fertilizer. Improved pastures are also often used for grazing livestock with manure deposition on the land, thus, providing a potential source of bacteria via runoff. Similar to cultivated cropland, only 1.5 percent of the watershed is classified as pasture/hay, thus, likely a limited source of nonpoint source nutrients and bacteria.

As there are no CAFOs in the watershed, there are no documented animal waste application fields.

## On-Site Sewage Facilities

On-site sewage facilities (OSSFs) are often referred to as septic systems. These small waste management systems are generally associated with houses that are unable to connect to a central wastewater collection system. Septic systems are often used in rural areas, but may also exist in urban areas when subdivisions develop outside the area serviced by a centralized waste management system or when areas are annexed that have OSSFs that have not yet connected to a city's central waste management system. Within the Nolan Creek/South Nolan Creek watershed, the Bell County Health District deals with permitting of all new OSSFs. While there is tracking of new systems through the permitting process, older or "grandfathered" systems (generally prior to 1989) are sometimes difficult to track, because permits were not required for these. At this time, a complete inventory of OSSFs within the watershed does not exist and available information for most of the watershed is not in a format that is easily mapped. Some locations of OSSFs were made available by the City of Killeen in a GIS format as part of its Septic Tank Elimination Program (STEP) and the location of these is shown in Figure 4-3.



**Figure 4-3** Location of some OSSFs within the Nolan Creek/South Nolan Creek watershed. Source: City of Killeen.

In the previous 319 study (Nett and Flowers, 2008), which focused on the upper third of the South Nolan Creek drainage area, the density of septic systems was found to be positively correlated with in-stream bacteria concentrations. When properly designed, installed, operated, and maintained, OSSFs can provide appropriate treatment of wastewater, but malfunctioning systems have been recognized to contribute significant loads of nutrients and bacteria, particularly if in close proximity to receiving water bodies (EPA, 2008). While the number of failing systems within the Nolan Creek/South Nolan Creek watershed is difficult to estimate, it is a recognized problem and steps are being taken in various areas to aid in resolving it. Of note, the City of Killeen started a Septic Tank Elimination Program (STEP) over 10 years ago, which aids homeowners in connecting to the city's sewer lines.

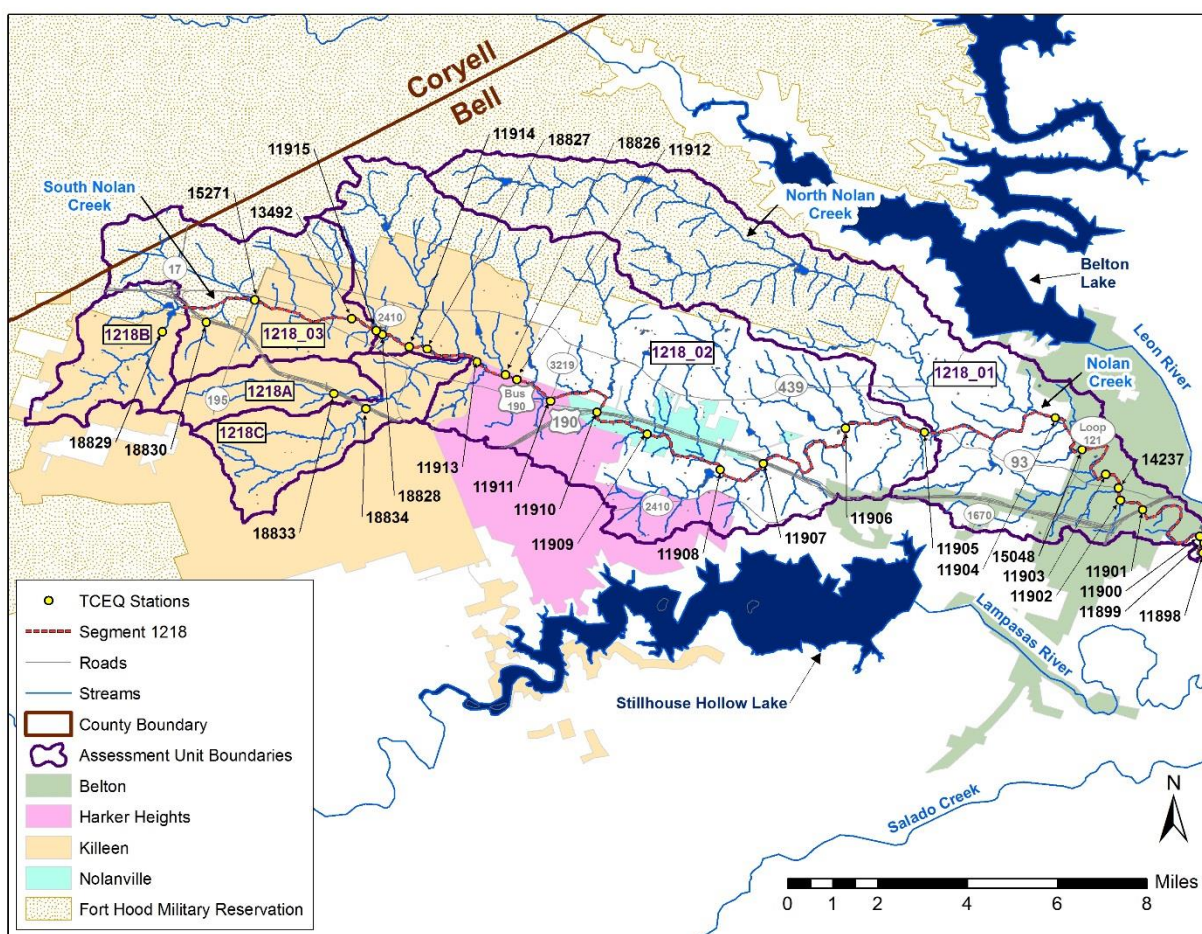
Because there does not exist a complete inventory of OSSFs for the watershed, estimations will be made for use in SELECT by identifying the areas not covered by a centralized collection system and overlaying that with 2010 Census data. Masking out the area serviced by sewer systems, about 2,180 households exist in the Nolan Creek/South Nolan Creek watershed that are expected to be on OSSFs. This information in conjunction with the site-specific data provided by the City of Killeen will be used to determine the relative density of OSSFs within subwatershed areas for use with SELECT. The density of OSSFs in the area above water quality monitoring stations will also be used to determine if a relationship exists between OSSF density and stream water quality.

## SECTION 5

### Water Quality Data and Trends

#### Period of Record

Water quality data through December 2013 were obtained through TCEQ's publicly available online Surface Water Quality Monitoring Information System (SWQMIS) for stations within Segment 1218 (TCEQ, 2014c). Data submitted to SWQMIS must follow strict protocols regarding data review and management for quality assurance (see TCEQ, 2013 as an example). These data were downloaded on October 1, 2014 from SWQMIS. Of the 31 stations with TCEQ station identification numbers for Segment 1218 (Table 5-1 and Figure 5-1), only 19 stations had bacteria data and 15 had nutrient data for nitrate, orthophosphorus (ortho-P), or total phosphorus (total-P) (Tables 5-2 and 5-3).



**Figure 5-1** Location of TCEQ stations within the Nolan Creek/South Nolan Creek watershed.

**Table 5-1** SWQMIS water quality monitoring stations associated with Nolan Creek/South Nolan Creek, Segment 1218.

<b>TCEQ Station No.</b>	<b>Station Location Description</b>	<b>Station Type</b>	<b>Latitude</b>	<b>Longitude</b>
11898	Nolan Creek near Leon River Confluence	Mainstem	31.03775	-97.4378
11899	Nolan Creek downstream Temple-Belton Regional WWTP outfall	Mainstem	31.04111	-97.4375
11900	Nolan Creek upstream Temple-Belton Regional WWTP outfall	Mainstem	31.04321	-97.4388
11901	Nolan Creek downstream of IH 35 in Belton	Mainstem	31.05167	-97.4572
11902	Nolan Creek at SH 317 in Belton	Mainstem	31.05476	-97.4644
14237	Nolan Creek at SH 93 in Belton	Mainstem	31.05874	-97.4650
11903	Nolan Creek at Burnett St in Belton	Mainstem	31.06314	-97.4692
15048	Nolan Creek at Loop 121 west of Belton	Mainstem	31.07104	-97.4767
11904	Nolan Creek at Wheat Rd	Mainstem	31.08130	-97.4853
11905	South Nolan Creek at Backstrom Crossing near FM93	Mainstem	31.07667	-97.5275
11906	South Nolan Creek at Patty Hamilton Rd	Mainstem	31.07805	-97.5530
11907	South Nolan Creek at US 190 east of Nolanville	Mainstem	31.06656	-97.5795
11908	South Nolan Creek at Nolanville Rd near US 190	Mainstem	31.06467	-97.5933
11909	South Nolan Creek at Old Nolanville Rd	Mainstem	31.07611	-97.6169
11910	South Nolan Creek at US 190 east of Harker Heights	Mainstem	31.08310	-97.6331
11911	South Nolan Creek at FM 3219	Mainstem	31.08667	-97.6481
11912	South Nolan Creek at Amy Lane	Mainstem	31.09361	-97.6589
18826	South Nolan Creek at Ann Blvd in Killeen	Mainstem	31.09518	-97.6626
11913	South Nolan Creek at Roy Reynolds Dr	Mainstem	31.09938	-97.6717
18827	South Nolan Creek at Twin Creek Dr in Killeen	Mainstem	31.10347	-97.6879
11914	South Nolan Creek near 56th St in Killeen	Mainstem	31.10425	-97.6937
18828	South Nolan Creek at 38th St in Killeen	Mainstem	31.10809	-97.7022
11915	South Nolan Creek upstream of Bell Count WCID 1 WWTP outfall	Mainstem	31.10950	-97.7043
13492	South Nolan Creek at W.S. Young Dr in Killeen	Mainstem	31.11324	-97.7122
15271	South Nolan Creek at SH 195 in Killeen	Mainstem	31.11933	-97.7434
18830	Bermuda Ditch at US 190 in Killeen	Tributary	31.11210	-97.7590
18829	South Nolan Creek at Watercrest Rd in Killeen	Mainstem	31.10905	-97.7732
21436	Long Branch above South Nolan Creek	Tributary	31.10521	-97.6894
21437	Little Nolan Creek at US 190 Business	Tributary	31.09736	-97.6922
18833	Unnamed tributary of Little Nolan Creek at US 190	Tributary	31.08907	-97.7179
18834	Little Nolan Creek at US 190	Tributary	31.08423	-97.7076

Of the 31 sampling stations, 12 are currently included in routine monitoring conducted by the TIAER, as part of Phase 2 of this project, or the BRA under the Clean Rivers Program. The BRA is conducting quarterly routine monitoring at station 11907, while TIAER is conducting routine monthly monitoring at 11 stations and quarterly storm monitoring at 4 stations (Table 5-4). Routine monitoring by TIAER was initiated in May 2013 as part of the current Clean Water Act §319(h) project and is scheduled to continue through May 2015.

For bacteria data prior to 2001, only fecal coliform was evaluated (Table 5-2). Starting in 2001 through 2004, both *E. coli* and fecal coliform were evaluated at some stations at TCEQ transitioned from use of fecal coliform as the indicator parameter for contact recreation to *E. coli*. At station 11907, there are 21 paired observations with fecal coliform and *E. coli* results, which may allow a comparison of values between these two bacteria indicators (Figure 5-2).

**Table 5-2** Period of record and number of bacteria samples through December 2013 for Nolan Creek/South Nolan Creek sampling stations. Data obtained from SWQMIS (TCEQ, 2014b).

AU	Station	Start Date Fecal Coliform Samples	End Date Fecal Coliform Samples	Number of Fecal Coliform Samples <sup>a</sup>	Start Date <i>E. coli</i> Samples	End Date <i>E. coli</i> Samples	Number of <i>E. coli</i> Samples <sup>a</sup>
1218_01	14237	28-Sep-94	9-Jul-97	13	13-Feb-13	12-Dec-13	12
1218_01	15048				7-Nov-11	26-Jun-12	4
1218_02	11905	18-Jul-96	18-Jul-96	1	8-May-13	12-Dec-13	10
1218_02	11907	29-Apr-80	19-Apr-04	132	23-Jan-01	19-Dec-13	64
1218_02	11908	26-Mar-74	20-Feb-80	24	8-May-13	12-Dec-13	8
1218_02	11910				8-May-13	12-Dec-13	10
1218_02	11911	19-Jul-96	19-Jul-96	1	8-May-13	12-Dec-13	8
1218_02	11913	19-Jul-96	19-Jul-96	1	4-Oct-06	12-Dec-13	24
1218_02	18826				4-Oct-06	19-Feb-08	14
1218_02	18827				4-Oct-06	12-Dec-13	22
1218_02	18828				4-Oct-06	12-Dec-13	24
1218_02	21436				8-May-13	12-Dec-13	8
1218_03	11915	26-Feb-90	19-Jul-96	10	8-May-13	12-Dec-13	8
1218_03	15271				4-Oct-06	19-Feb-08	14
1218_03	18830				18-Apr-07	13-Sep-07	5
1218A	18833				4-Oct-06	19-Feb-08	14
1218B	18829				4-Oct-06	19-Feb-08	14
1218C	18834				4-Oct-06	19-Feb-08	14
1218C	21437				8-May-13	12-Dec-13	8

- a. For fecal coliform, samples represent parameter code 31616 (fecal coliform, membrane filter, m-fecal coliform broth) and for *E. coli*, samples represent parameter code 31699 (*E. coli*, Colilert, IDEXX method).

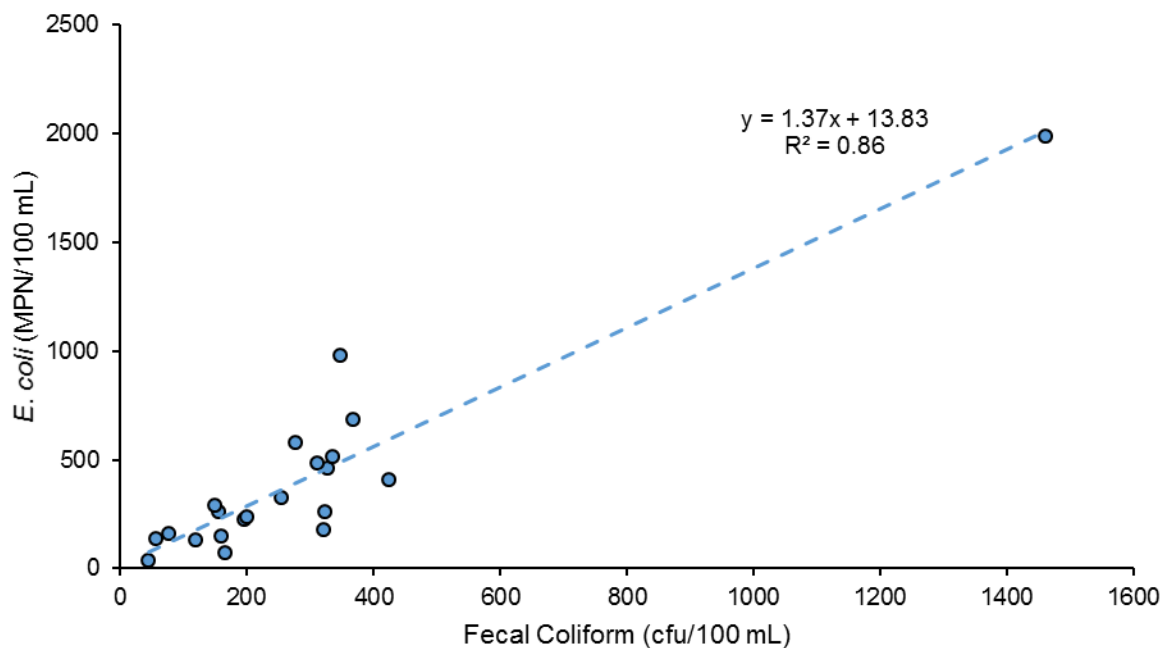
**Table 5-3** Period of record and number of nitrate, orthophosphorus, and total phosphorus samples through December 2013 for Nolan Creek/South Nolan Creek sampling stations. Data obtained from SWQMIS (TCEQ, 2014b).

AU	station	Start Date Nitrate Samples	End Date Nitrate Samples	Number of Nitrate Samples	Start Date Ortho-P Samples	End Date Ortho-P Samples	Number of Ortho-P Samples	Start Date Total-P Samples	End Date Total-P Samples	Number of Total- P Samples
1218_01	14237	28-Sep-94	12-Dec-13	26	28-Sep-94	12-Dec-13	20	28-Sep-94	12-Dec-13	25
1218_01	15048	7-Nov-11	26-Jun-12	5				7-Nov-11	26-Jun-12	4
1218_02	11905	9-Apr-80	12-Dec-13	11	9-Apr-80	12-Dec-13	12	9-Apr-80	12-Dec-13	12
1218_02	11907	9-Apr-80	19-Dec-13	170	9-Apr-80	19-Sep-13	163	9-Apr-80	19-Dec-13	151
1218_02	11908	28-Mar-74	12-Dec-13	32	28-Mar-74	12-Dec-13	31	28-Mar-74	12-Dec-13	32
1218_02	11910	9-Apr-80	12-Dec-13	12	9-Apr-80	12-Dec-13	12	9-Apr-80	12-Dec-13	12
1218_02	11911	9-Apr-80	12-Dec-13	10	9-Apr-80	12-Dec-13	10	9-Apr-80	12-Dec-13	10
1218_02	11913	9-Apr-80	12-Dec-13	23	9-Apr-80	12-Dec-13	23	9-Apr-80	12-Dec-13	20
1218_02	18827	11-Jan-07	12-Dec-13	11	11-Jan-07	12-Dec-13	11	18-Jul-07	12-Dec-13	10
1218_02	18828	11-Jan-07	12-Dec-13	13	11-Jan-07	12-Dec-13	13	18-Jul-07	12-Dec-13	12
1218_02	21436	8-May-13	12-Dec-13	8	8-May-13	12-Dec-13	8	8-May-13	12-Dec-13	8
1218_03	11915	9-Apr-80	12-Dec-13	20	9-Apr-80	12-Dec-13	20	9-Apr-80	12-Dec-13	20
1218_03	15271	11-Jan-07	9-Jan-08	3	11-Jan-07	9-Jan-08	3	18-Jul-07	9-Jan-08	2
1218B	18829	11-Jan-07	9-Jan-08	3	11-Jan-07	9-Jan-08	3	18-Jul-07	9-Jan-08	2
1218C	21437	8-May-13	12-Dec-13	8	8-May-13	12-Dec-13	8	8-May-13	12-Dec-13	8

- In evaluating nitrate values, assessments often include the combination of nitrite plus nitrate-nitrogen, because these two forms of nitrogen can be difficult to separate and because nitrite is generally only a small portion of nitrite plus nitrate. Parameter codes representing nitrate samples included 00620 (nitrate nitrogen, total), 00630 (nitrite plus nitrate, total one lab determined value), 00631 (nitrite plus nitrate, dissolved one lab determined value), and 00593 (nitrite plus nitrate, total calculated value). Generally only one parameter value was present for a given sample, but if more than one parameter had values, only one was included in summing samples.
- For ortho-P, parameter values 00671 (orthophosphate phosphorus, dissolved, field filter < 15 min) and 70507 (orthophosphate phosphorus, dissolved, filter > 15 min). In all cases, only one parameter or the other had a value for a given sample.
- For total-P, sample numbers represent values for parameter code 00665 (phosphorus, total, wet method).

**Table 5-4** Routine and storm monitoring stations for Nolan Creek/South Nolan Creek as of December 2013. Routine monthly and storm quarterly monitoring is conducted by TIAER, while routine quarterly monitoring is conducted by the BRA.

AU	Station	Routine Monthly	Routine Quarterly	Storm Quarterly
1218_01	14237	X		
1218_02	11905	X		X
1218_02	11907		X	
1218_02	11908	X		
1218_02	11910	X		X
1218_02	11911	X		
1218_02	11913	X		X
1218_02	18827	X		
1218_02	18828	X		X
1218_02	21436	X		
1218_03	11915	X		
1218C	21437	X		



**Figure 5-2** Comparison of fecal coliform with *E. coli* results from paired observations from station 11907.

## Assessment Review

To confirm the TCEQ assessment of AUs within the Nolan Creek/South Nolan Creek watershed, historical water quality data for each AU were evaluated using TCEQ assessment guidance for data collected between December 1, 2003 and November 30, 2010 (TCEQ, 2012). While the assessment guidance indicates a focus on samples collected at 0.3 meters (1 ft) below the water surface, in calculating the geometric mean of *E. coli* for AUs 1218B and 1218C, it appears that all samples were used in the assessment regardless of depth (Table 5-5). All samples for AUs 1218B and 1218C were taken at depths below 0.3 m. For all other AUs, except 1218\_01 at which no samples were collected during the assessment period, only samples collected at depths of 0.3 m appear to have been used in the 2012 assessment. The few samples collected at shallower depths than 0.3 m were excluded in the bacteria assessment for AUs 1218A, 1218\_02, and 1218\_03, although results based on samples from all depths are shown in Table 5-5.

The results shaded in grey in Table 5-5 match those presented by TCEQ for the 2012 Texas Water Quality Inventory and confirm the bacteria impairment for AUs 1218\_02 and 1218C noted on the Texas 303(d) list with geometric mean values for *E. coli* greater than the criterion of 126 cfu/100 mL. If samples from all depths rather than just those from 0.3 m are used, the assessment of water quality changes only for AU 1218A, which is an unnamed tributary to Little Nolan Creek (AU 1218C), to indicate a potential bacteria impairment in AU 1218A.

For nutrients of concern (nitrates, ortho-P, and total-P), historical data were also reviewed using the TCEQ assessment guidance (TCEQ, 2012; Table 5-6). Only an adequate number of nutrient samples (> 10 samples) were available for AU 1218\_02. All other AUs had three or fewer nutrient with samples analyses during the assessment time period (December 1, 2003 and November 30, 2010). In summary, this evaluation confirmed the concerns noted for nitrates, ortho-P, and total-P with greater than 90 percent of samples exceeding the nitrate and ortho-P screening levels and over 50 percent of sample values exceeding the total-P screening level.

**Table 5-5** Assessment of bacteria for AUs within the Nolan Creek/South Nolan Creek based on samples collected between December 1, 2003 and November 30, 2010. Results shaded in gray represent assessment results as presented in the 2012 Texas Integrate Report (TCEQ, 2013c). *E. coli*, samples represent parameter code 31699 (*E. coli*, Colilert, IDEXX method).

AU	Geometric Mean <i>E. coli</i> (MPN/100 mL), all depths	# Obs. (all depths)	Geometric Mean <i>E. coli</i> (MPN/100 mL), depth = 0.3 m	# Obs. (depth = 0.3 m)
1218A	157	14	120	8
1218B	59	14	No data	0
1218C	164	14	No data	0
1218_01	No data	0	No data	0
1218_02	187	81	188	80
1218_03	89	19	49	13

**Table 5-6** Assessment of nutrients in comparison to screening levels for AU 1218\_02 within the Nolan Creek/South Nolan Creek based on samples collected between December 1, 2003 and November 30, 2010.

Nutrient	# Obs.	Mean	# Obs. > Screening Level	Mean of Obs. above Screening Level	Screening Level	Parameter Codes and Descriptions	Comments
Nitrate	35	7.7 mg/L	33	8.09 mg/L	1.95 mg/L	00620 (nitrate nitrogen, total) or 00631 (nitrite plus nitrate, dissolved one lab determined value)	Depth of samples $\leq$ 0.3 m
Ortho-P	36	1.35 mg/L	33	1.45 mg/L	0.37 mg/L	00671 (orthophosphate phosphorus, dissolved, field filter < 15 min)	Excludes samples with values analyzed based on parameter code 70507 (orthophosphate phosphorus, dissolved, filter > 15 min); sample depths all $\leq$ 0.3 m
Total-P	24	1.42 mg/L	13	2.14 mg/L	0.69 mg/L	00665 (phosphorus, total, wet method)	All depths considered but excludes total-P values when ortho-P > total-P by 5% or more

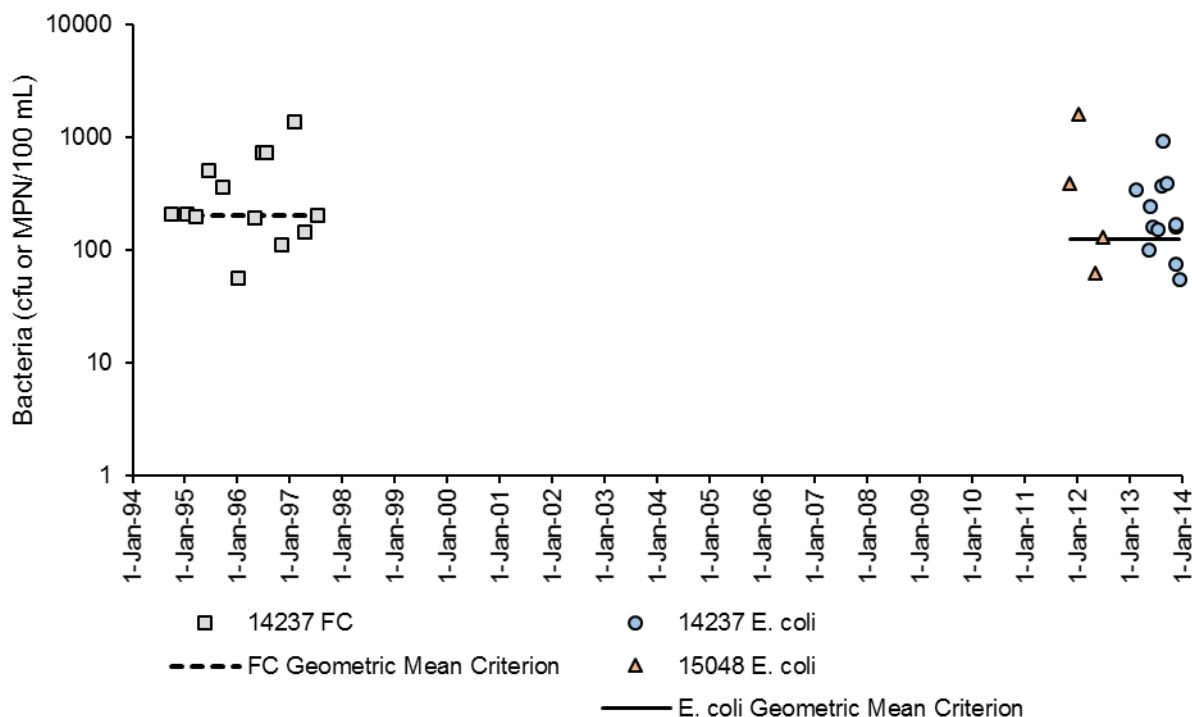
## Water Quality over Time

Bacteria and nutrient values were plotted over time to give a better picture of data availability and potential temporal trends. These data were plotted by AU with individual stations identified to aid in a spatial evaluation of available data. For bacteria data, fecal coliform was monitoring predominately prior to 2001 and was compared to the geometric mean fecal coliform criterion used at that time of 200 cfu/100 mL fecal coliform. After 2001, *E. coli* was dominant bacteria parameter monitored and values for reference are compared to the geometric mean *E. coli* criterion for primary contact recreation. For nutrients, values were compared to the screening levels of 1.95 mg/L for nitrate, 0.37 mg/L for ortho-P, and 0.69 mg/L for total-P.

### Bacteria

For AU 1218\_01, only two stations had bacteria data (14237 and 15048). Several fecal coliform samples were collected between 1994 and 1998, but then a large temporal gap occurs until monitoring was renewed in 2011 (Figure 5-3). As noted above, no sampling occurred during the 2012 assessment period (December 1, 2003 and November 30, 2010) in AU 1218\_01. The

current project is conducting monthly routine monitoring at station 14237, which was initiated in May 2013.



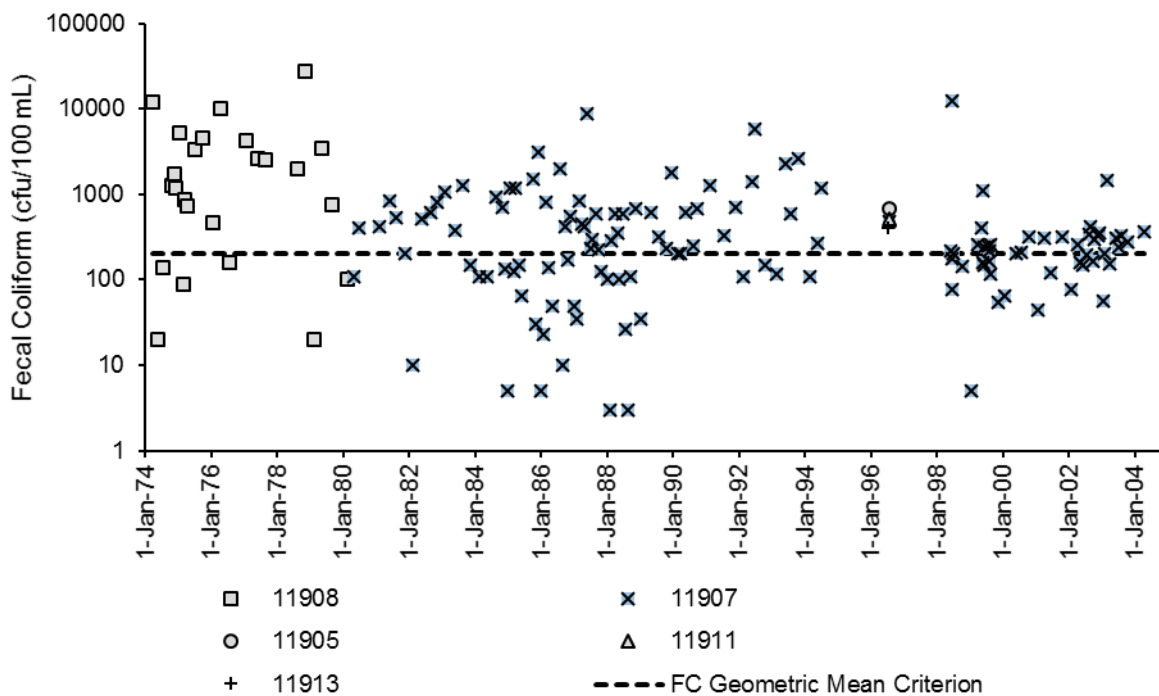
**Figure 5-3** Bacteria data over time for AU 1218\_01.

For AU 1218\_02, several stations have been monitored for both fecal coliform and *E. coli* (Figure 5-4 and 5-5). While most stations show only relatively short periods of monitoring, station 11907 shows a fairly consistent history of bacteria monitoring back to 1980 (Figure 5-6).

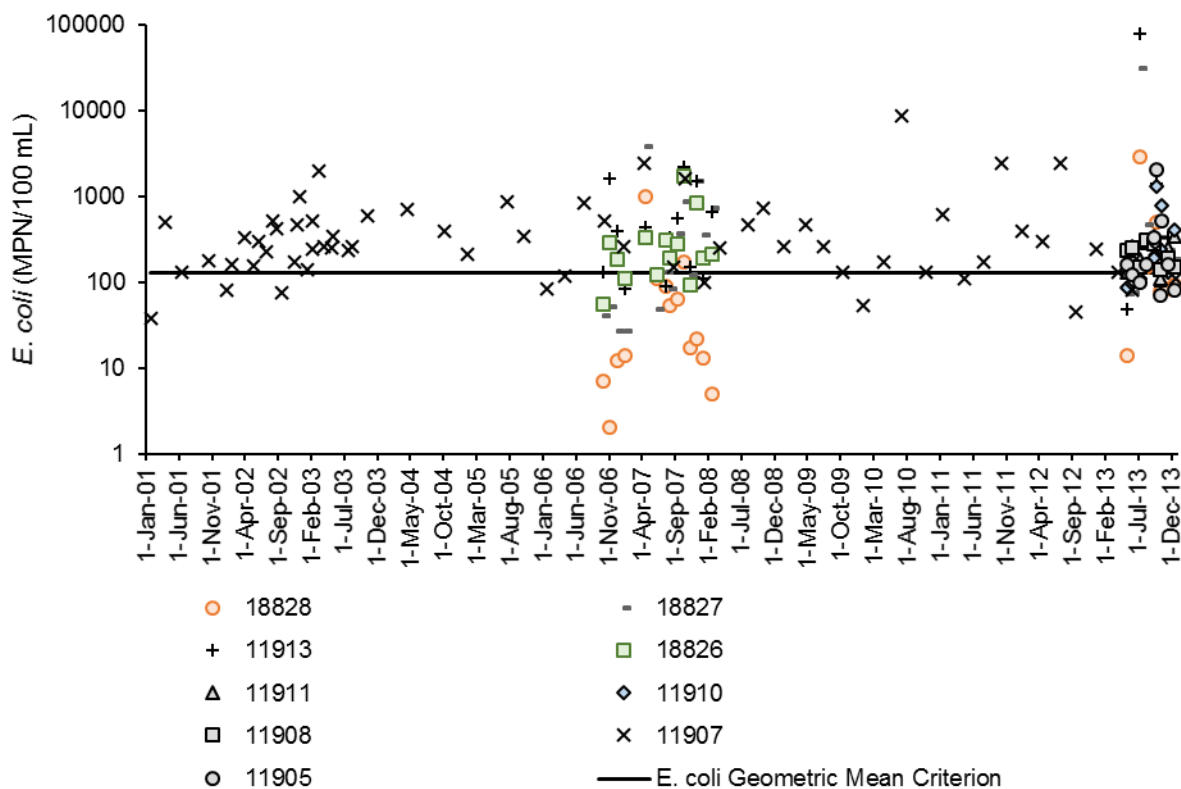
For AU 1218\_03, similar to AU 1218\_01, only two stations have any bacteria monitoring data. These are stations 11915 and 15271 (Figure 5-7). The bacteria data for AU 1218\_03 is very clustered with a period between 1990 and 1997 monitoring for fecal coliform at station 11915, a period between 2006 and 2009 at station 15271, and then starting again in 2013 at station 11915.

Bacteria data for AUs 1218A, 1218B, and 1218C is primarily focused between 2006 and 2008 with the current project picking up monitoring at station 21437 in 2013 (Figure 5-8).

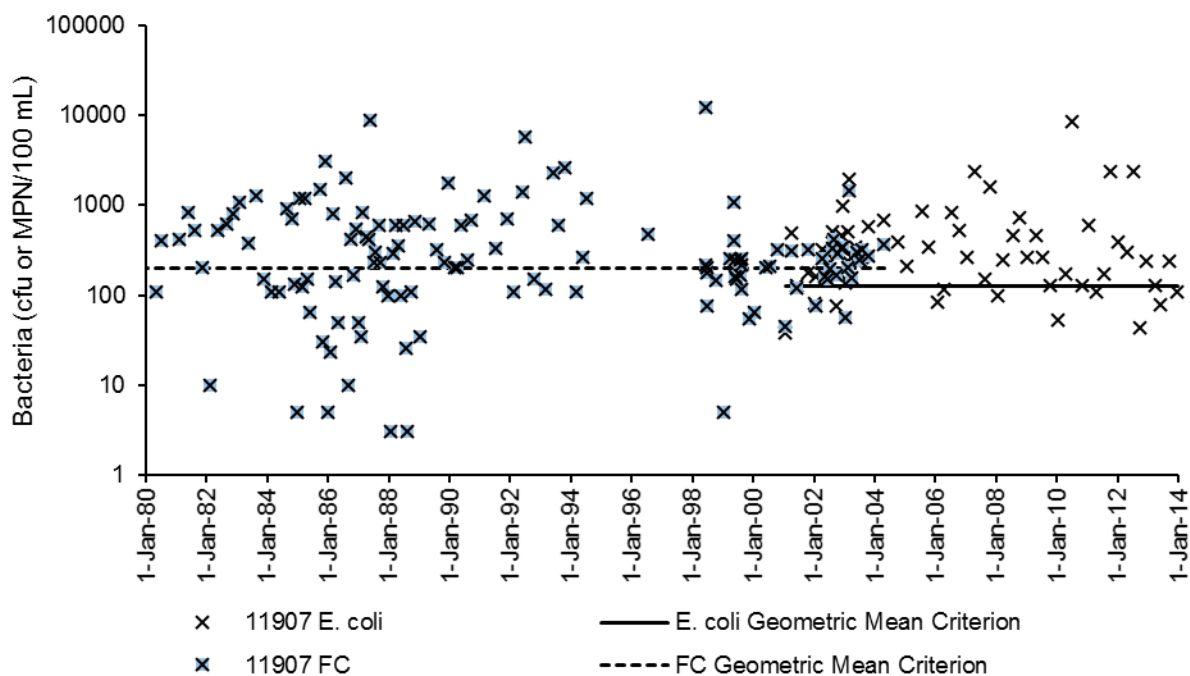
Bacteria values appear to scatter both sides of the assessment criterion indicating no trend over time, whether considering fecal coliform or *E. coli* data. A few stations, such as station 18829 in AU 1218B (Figure 5-8), station 11915 in AU 1218\_03 (Figure 5-7), and station 18828 in AU 1218\_02 (Figure 5-5), appear to show more frequent values below than above the assessment criterion potentially indicating areas of the creek in need of more focused control efforts.



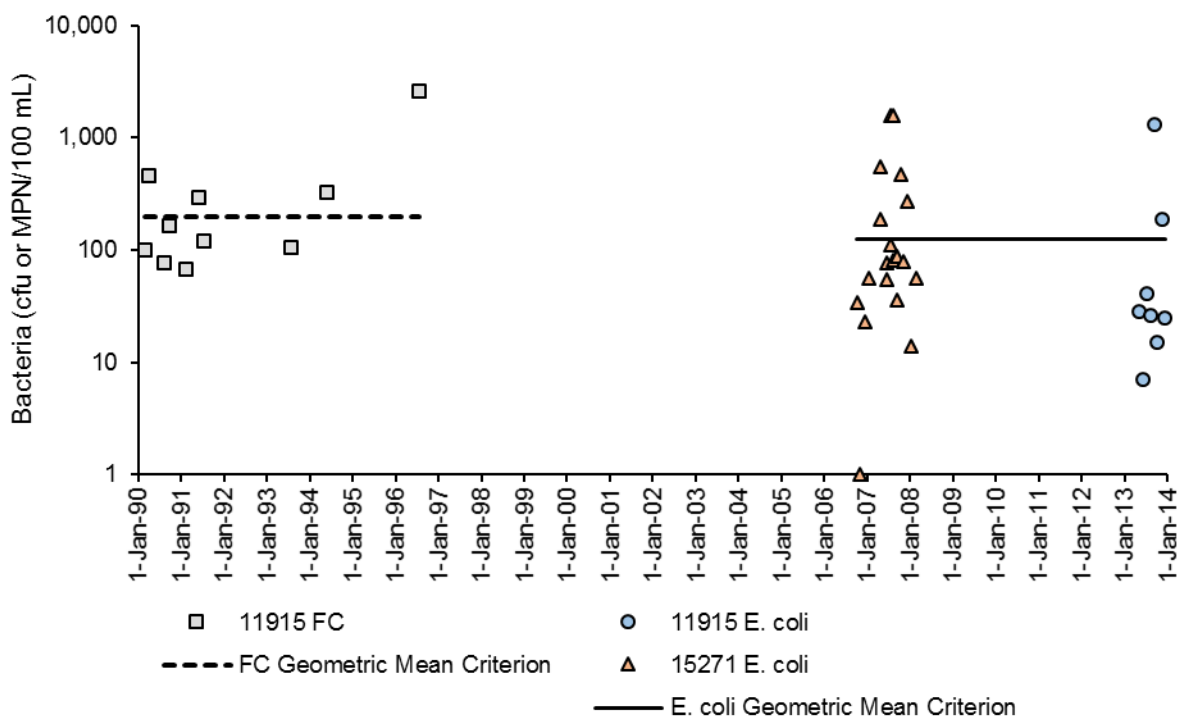
**Figure 5-4** Fecal coliform data over time for AU 1218\_02.



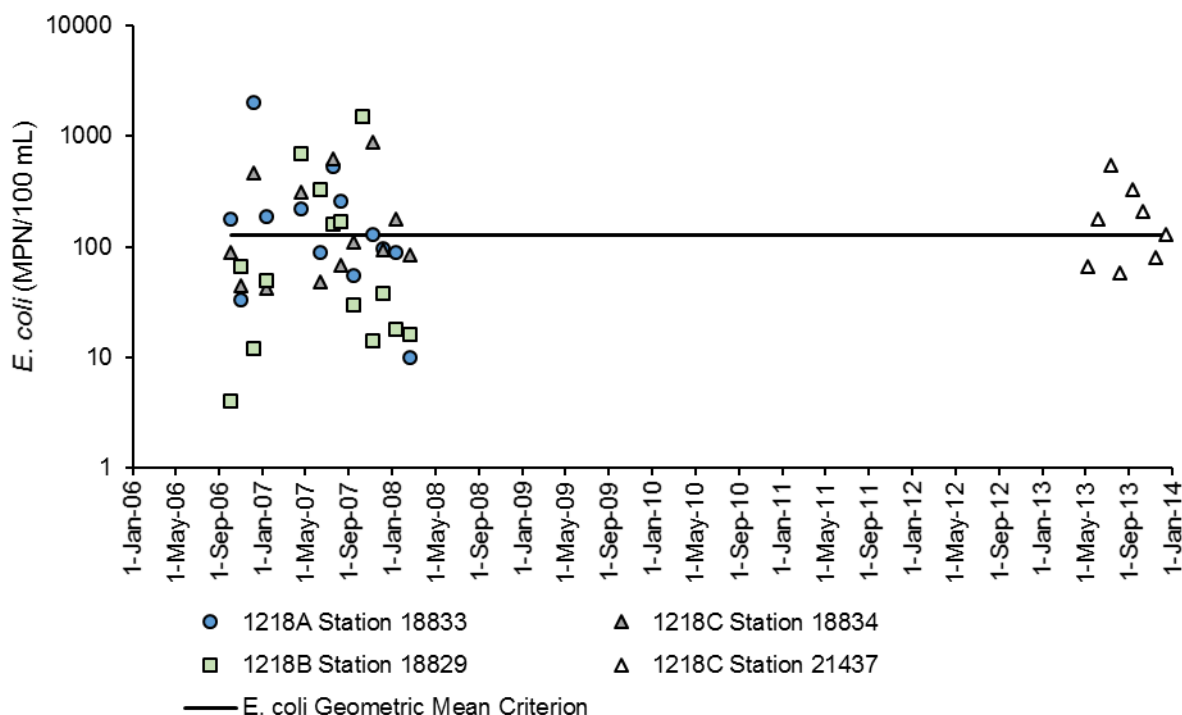
**Figure 5-5** *E. coli* data over time for AU 1218\_02.



**Figure 5-6** Bacteria data over time for station 11907 in AU 1218\_02.

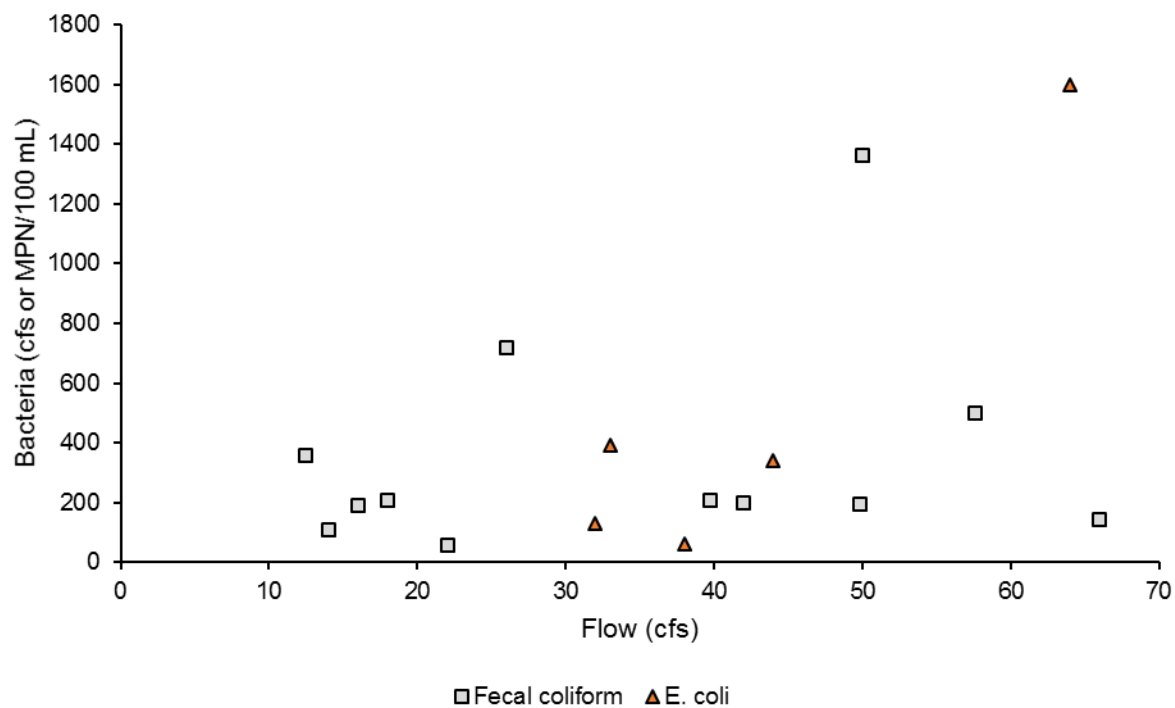


**Figure 5-7** Bacteria data over time for AU 1218\_03.

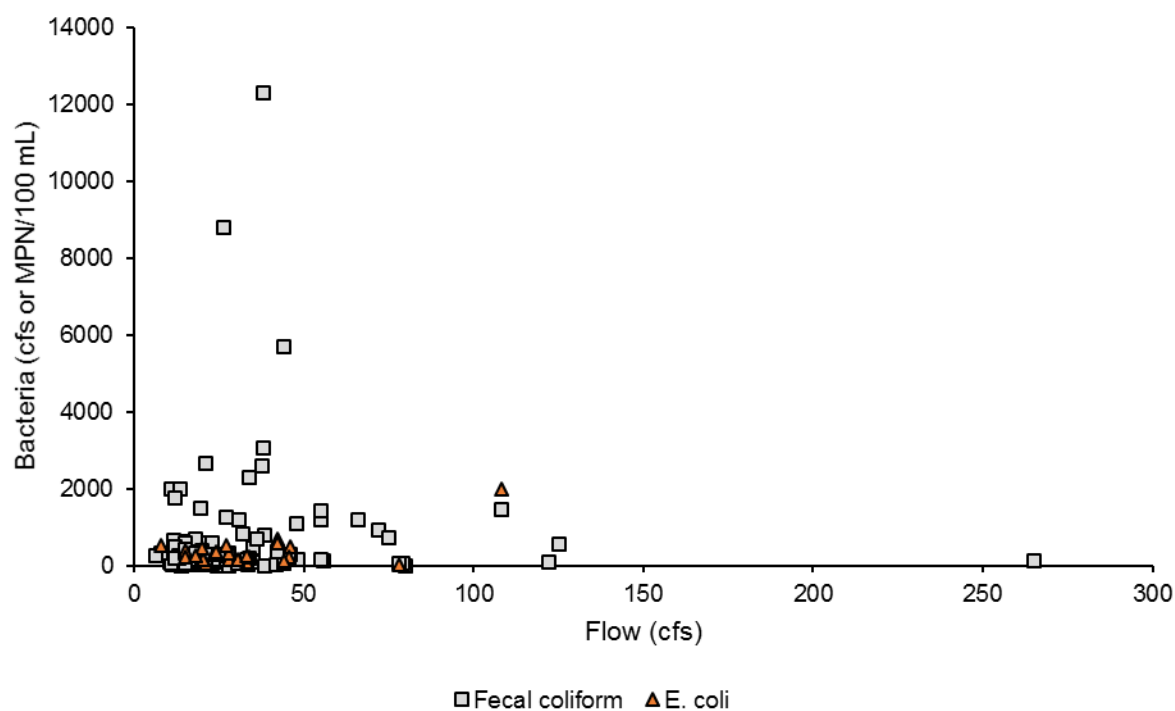


**Figure 5-8** Bacteria data over time for AU 1218A, 1218B, and 1218C.

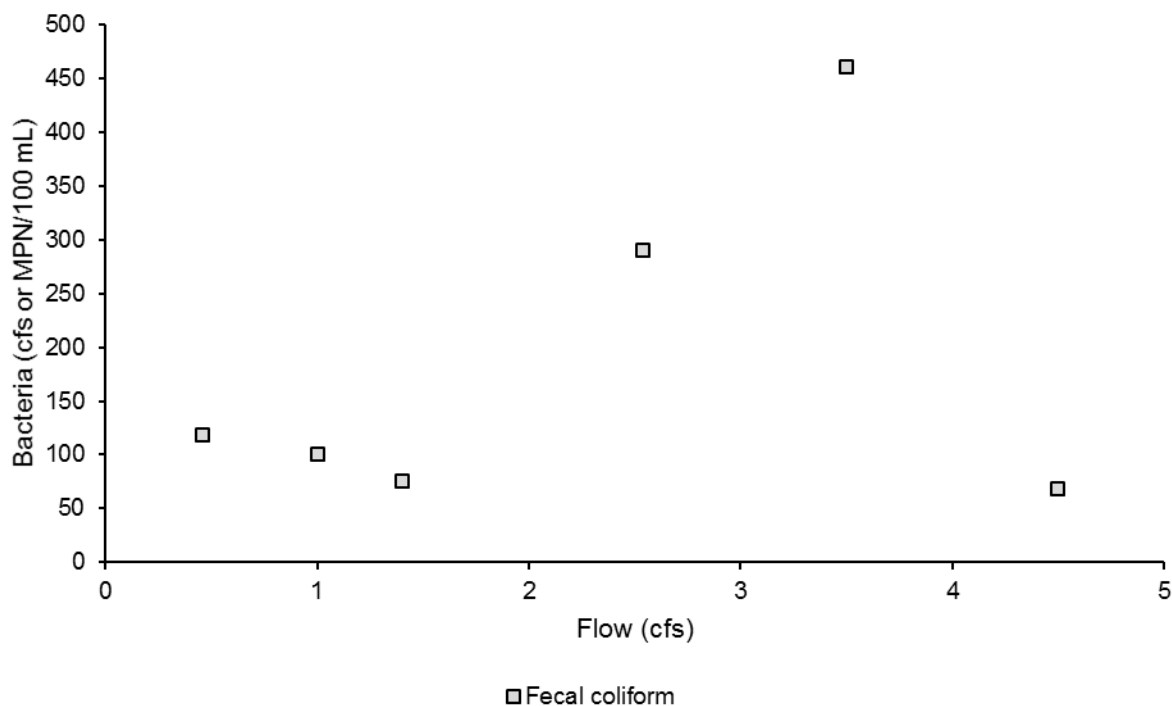
As flow can be strongly correlated with in-stream pollutant concentrations, the availability of flow data with bacteria concentrations was assessed. No flow measurements were available in association with bacteria data for AUs 1218\_A, 1218\_B, or 1218\_C within the SWQM dataset. For AUs 1218\_01, 1218\_02, and 1218\_03 combined, about 77 percent of all fecal coliform observations had flow data associated with them, while only 21 percent of *E. coli* observations had flow related data based on observation collected prior to May 2013 (when monitoring for the current project began). Plots of the bacteria data versus flow by AU showed that most paired flow and bacteria data were associated with flows of 50 cfs or lower (Figures 5-9 – 5-11). For AU 1218\_02, the impaired AU, there was no clear trend increasing or decreasing in bacteria concentrations with flow (Figure 5-10).



**Figure 5-9** Flow versus bacteria concentrations for AU 1218\_01.



**Figure 5-10** Flow versus bacteria concentrations for AU 1218\_02.

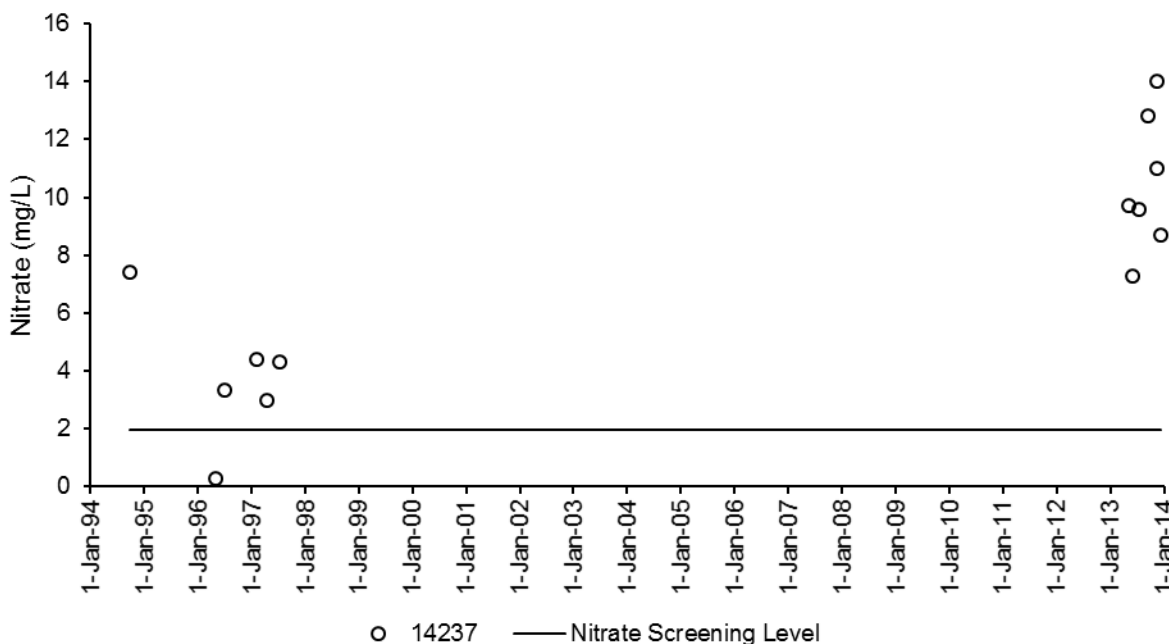


**Figure 5-11** Flow versus bacteria concentrations for AU 1218\_03.

### ***Nitrate***

For nitrates, there are subtle differences between different forms presented by various laboratory analyses. The majority of nitrate data presented are from parameter codes 00620 (nitrate nitrogen, total) and 00631 (nitrite plus nitrate, dissolved one lab determined value). When parameter code 00630 (nitrite plus nitrate, total one lab determined value) was reported, values for parameter code 00620 (nitrate nitrogen, total) were also reported, so only data for parameter code 00620 are presented. On several occasions in the late 1990s and early 2000s, nitrate data were reported only as parameter code 00593 (nitrite plus nitrate, total calculated value) without values for the separate nitrite and nitrate components, thus, on these occasions results for parameter code 00593 are presented. The various nitrate forms are not differentiated in the figures below, as differences are considered fairly minor in the general presentation of these results over time.

For AU 1218\_01, nitrate values were only available for station 14237. A large gap exists in the temporal history at this stations with some nitrate data collected in the mid-1990s and then not again until 2013 (Figure 5-12). Most values during both time periods show concentrations above the screening level of 1.95 mg/L for nitrates.

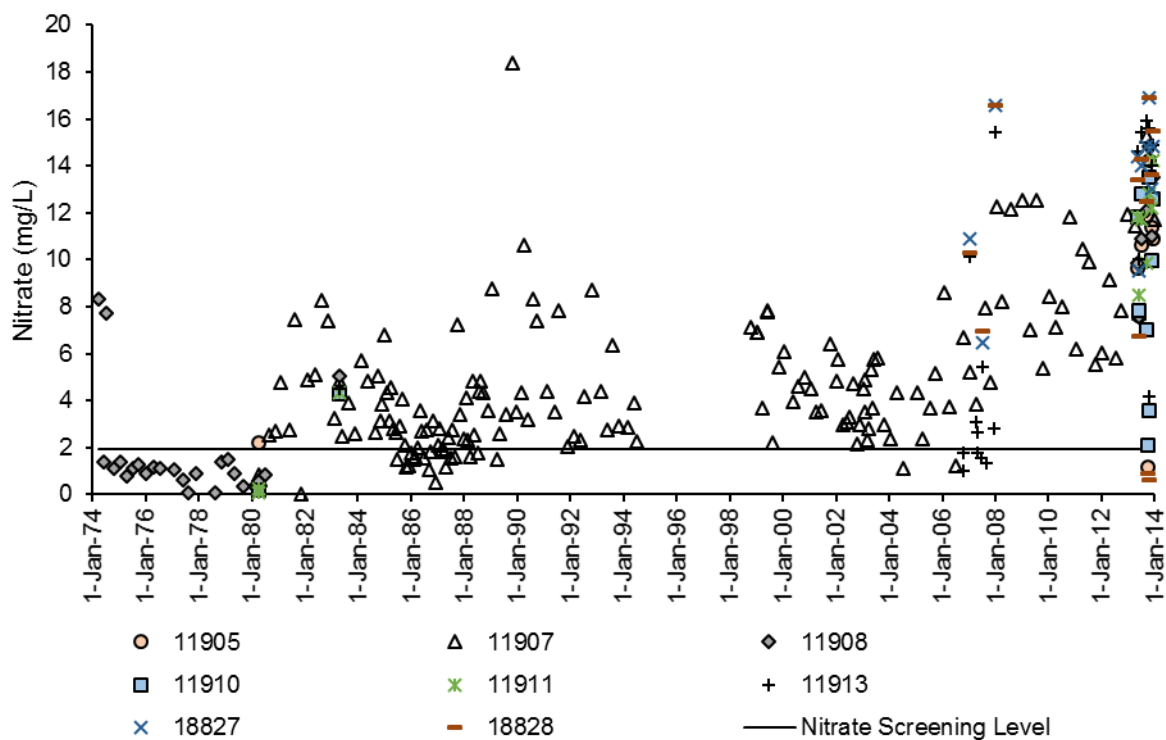


**Figure 5-12** Nitrate data over time for AU 1218\_01.

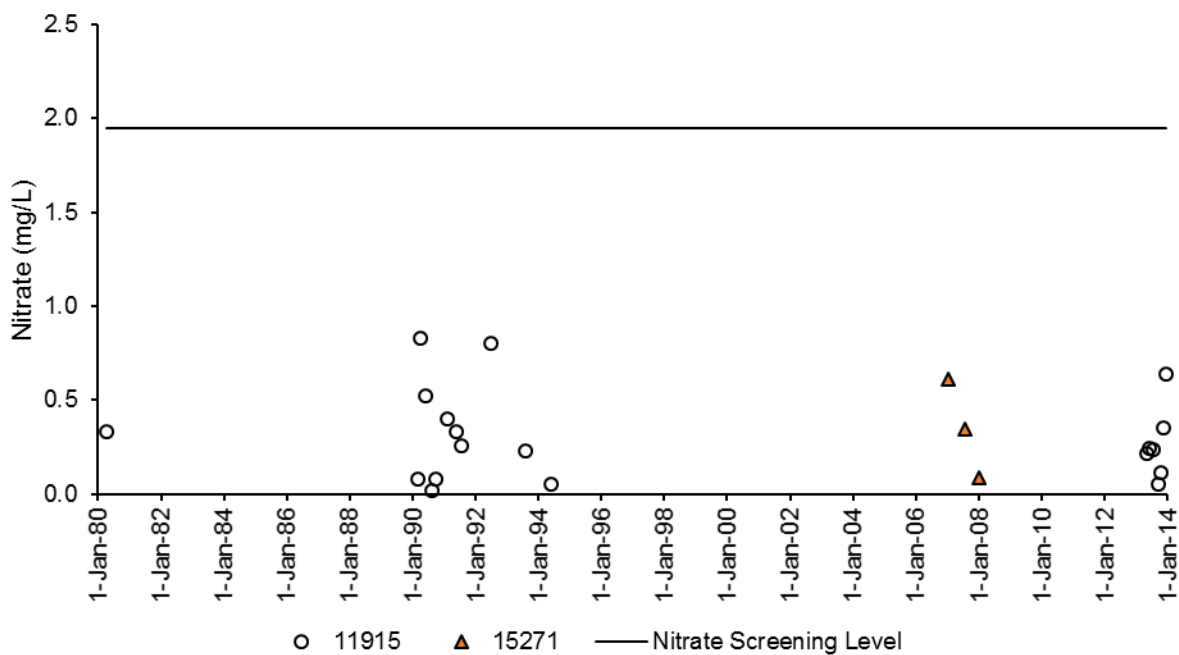
For AU 1218\_02, there appears to be an increase in nitrate concentrations in the early 1980s, but this also coincides with a change in the dominant sampling location from station 11908 to station 11907 (Figure 5-13). From 1980 through 2014, nitrate concentrations are largely above the nitrate screening level and at station 11907, nitrate concentrations appear to show a step increase in 2008 in comparison to prior concentrations. The density of data in 2013 indicates the current project's monthly, which was initiated in May 2013 at eight stations in AU 1218\_02. A more detailed analyses of these data collected as Phase 2 of the project will be presented in separate report comparing nitrate concentrations between sites as part of the identification of sources.

For AU 1218\_03, all nitrate samples collected had concentrations well below the nitrate screening level of 1.95 mg/L (Figure 5-14). While having only a few representative samples, the same was true for AU 1218B and 1218C (Figure 5-15). No nitrate values were within the SWQM dataset for AU 1218A, though because AU 1218A flows into 1218C and concentrations within 1218C appear to be low, it can be inferred that nitrate concentrations in AU 1218C are also likely low.

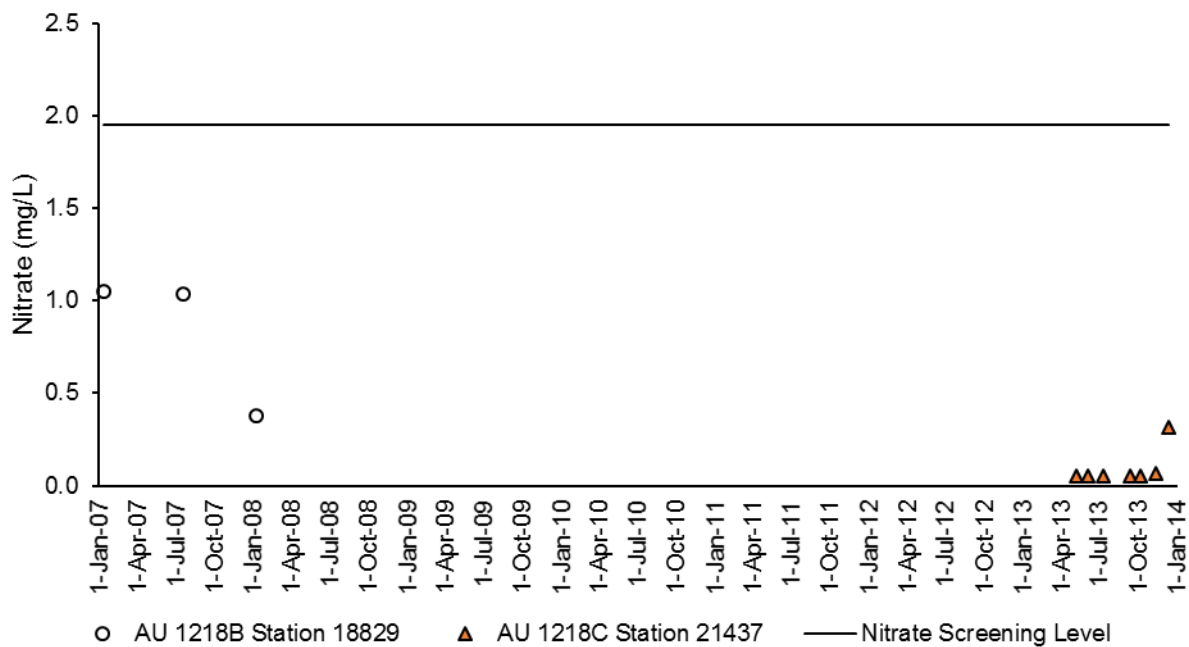
In evaluating nitrate concentrations in relation to flow, only about 45 percent of observations had paired nitrate and flow values. Plotted by AU, AUs 1218\_01 and 1218\_02 showed higher nitrate concentrations at lower flows (Figure 5-16). Of note, no direct point sources discharge to South Nolan Creek within AU 1218\_03, but several point source discharges occur along or above AUs 1218\_01 and 1218\_02. Increasing nitrate concentrations with decreasing flows may be an indicator of primarily point source contributions leading to higher nitrate concentrations.



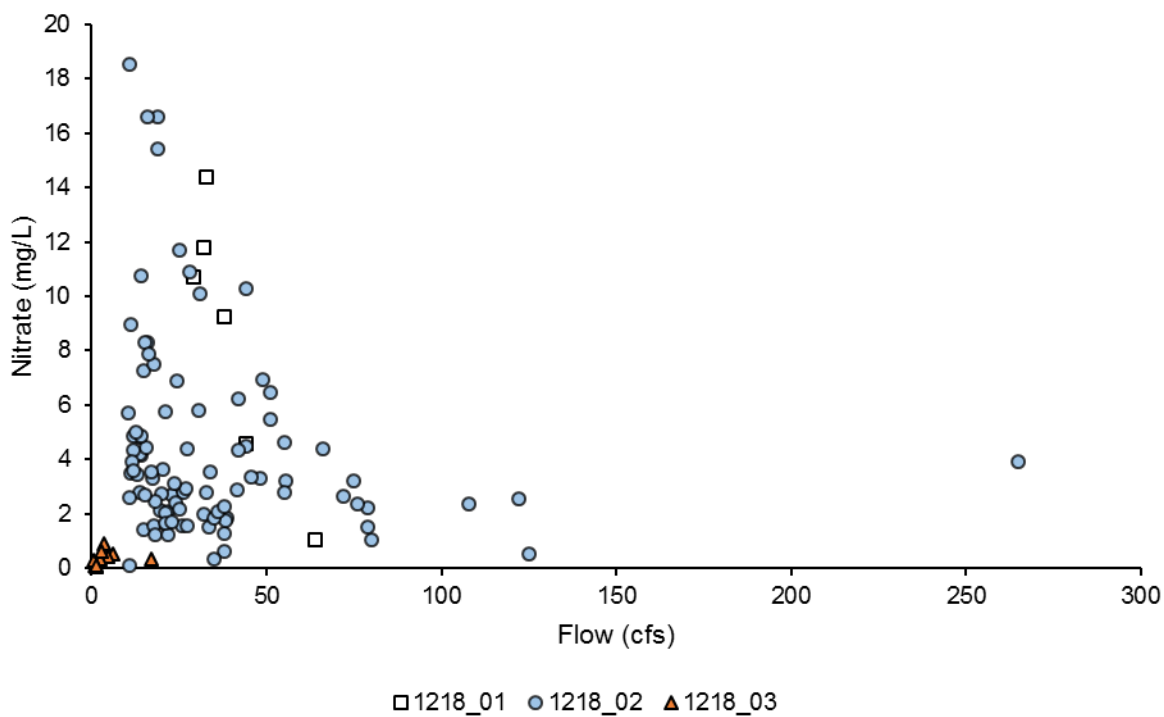
**Figure 5-13** Nitrate data over time for AU 1218\_02.



**Figure 5-14** Nitrate data over time for AU 1218\_03.



**Figure 5-15** Nitrate data over time for AU 1218B and 1218C.



**Figure 5-16** Flow versus nitrate concentrations by AU.

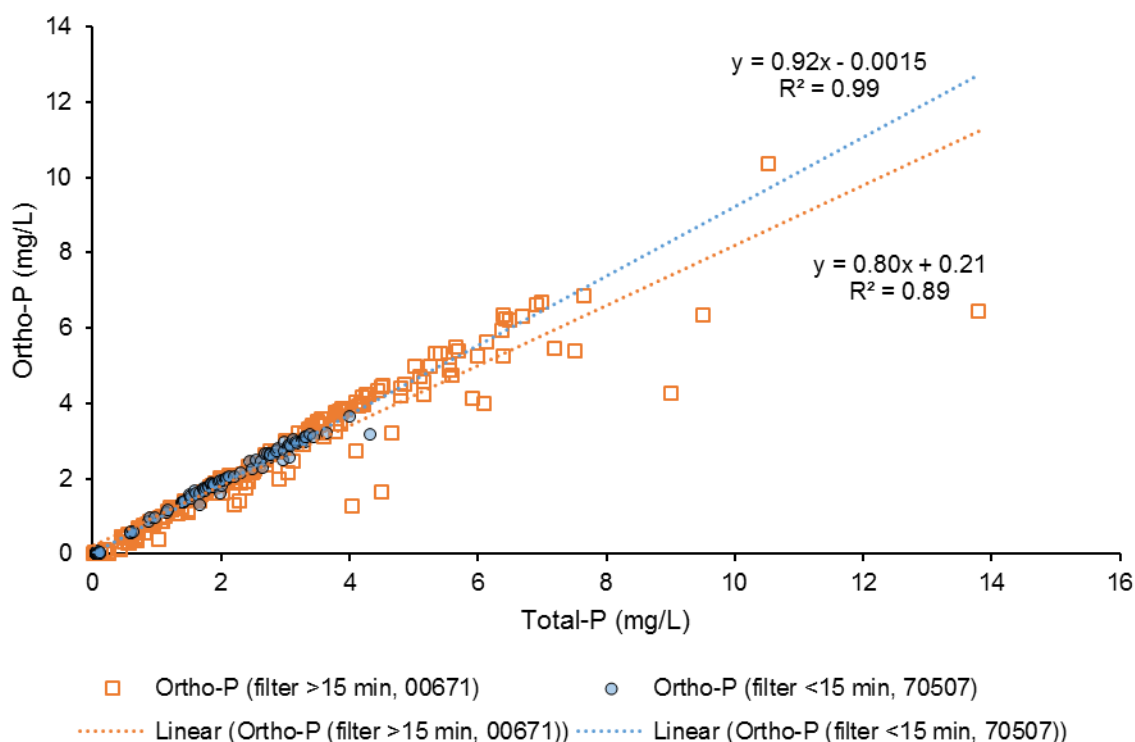
## Phosphorus

For total-P, all values in the SWQM database are presented as parameter code 00665 (phosphorus total, wet method) reported in mg/L as P. For ortho-P, as noted in Table 5-3, values occurred in the SWQM database as both parameter codes 00671 (ortho-P, dissolved, filter < 15 min) and 70507 (ortho-P, dissolved, filter > 15 min). While in more recent years parameter code 00671 was commonly associated with ortho-P values, prior to September 2003, ortho-P values were exclusively associated with parameter code 70507. A distinction is made between these two parameter codes based on the timing of filtration, because some transformations of ortho-P to total-P and vice versa can occur prior to filtering out the sediment particles. Because all samples with ortho-P analyses presented values for one parameter code or the other and not both, values by the two methods could not be directly compared. When a value for ortho-P was reported, almost always a value for total-P was also reported, so results for the two ortho-P methods could be compared indirectly based on their relationship with total-P.

Similar to the assessment evaluation, 14 samples showed ortho-P concentrations that were more than five percent greater than total-P concentrations (Table 5-7). These 14 samples were removed from the working dataset and a regression relationship of total-P with each ortho-P parameter was developed (Figure 5-17). While the regression relationship appeared to diverge at higher concentrations (Figure 5-17), the regression line for ortho-P (filter < 15 min, 00671) should be limited to the range of measured values and can only be extrapolated beyond total-P concentrations of 4.33 mg/L.

**Table 5-7** Samples indicating ortho-P concentrations more than five percent greater than total-P concentrations.

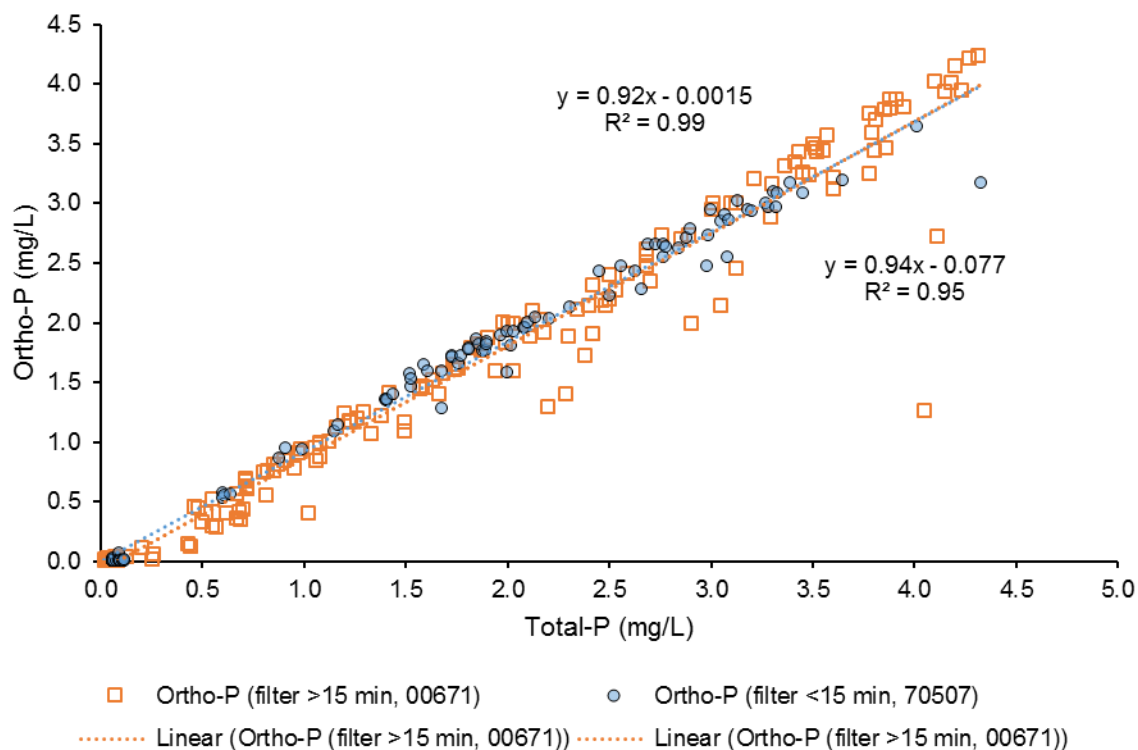
Date	Ortho-P, filtered <15 min (mg/L)	Ortho-P, filtered >15 min (mg/L)	Total-P (mg/L)
2-May-96		0.05	0.01
27-Jun-96		1.10	0.06
17-Apr-97		0.52	0.07
8-May-13	1.92		1.79
14-Oct-03	0.94		0.88
22-Jan-04	0.30		0.10
7-Oct-04	0.79		0.06
20-Jan-05	0.57		0.21
6-Apr-05	0.44		0.15
20-Jul-05	1.52		0.44
24-Mar-08	1.06		0.53
21-Apr-09	1.38		1.26
15-Apr-10	0.86		0.80
19-Jul-11	2.89		2.41



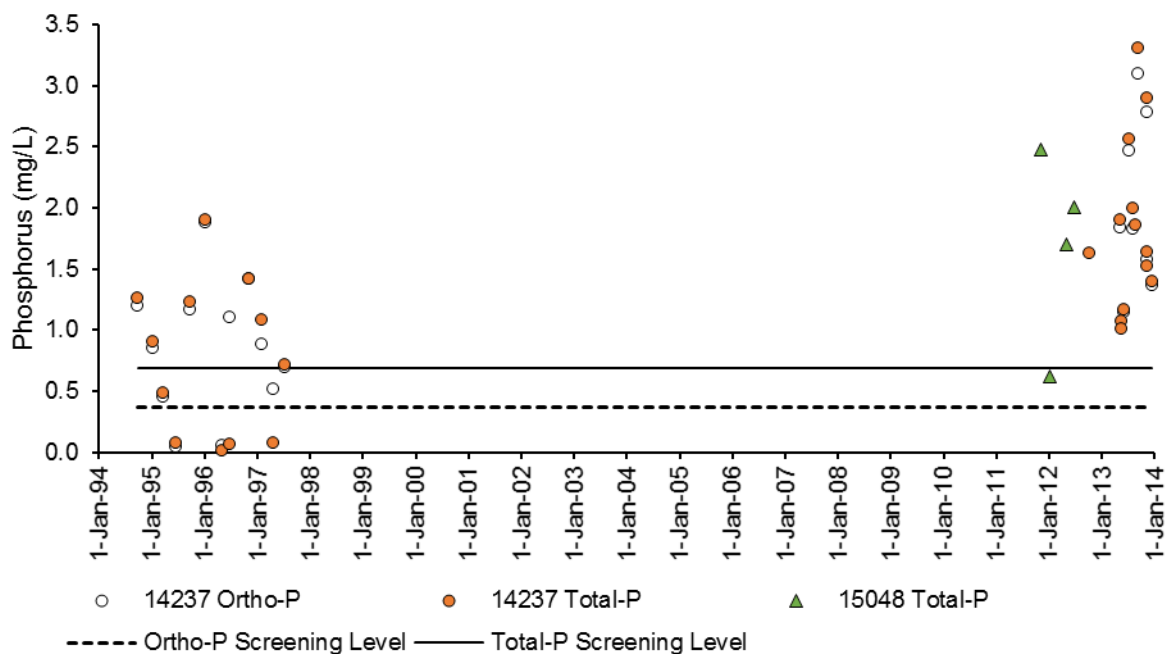
**Figure 5-17** Comparison of ortho-P for two different parameter codes with total-P concentrations for the full range of values.

Because the range of concentrations was much broader for ortho-P (filter > 15 min, 70507) than ortho-P (filter < 15 min, 00671), the range of dataset was then limited to comparable concentrations (Figure 5-18). This more limited dataset still represented over 75 percent of ortho-P results. A comparison of the two regression lines developed based on this comparable data range showed no statistically significant differences indicating that results from these two ortho-P methods are comparable for this dataset. Therefore, throughout the rest of this data presentation, ortho-P concentrations are presented without differentiating results between these two parameter codes to allow an evaluation of available data over time.

For AU 1218\_01, station 14237 had most of the observations with data occurring in the 1990s and starting again in 2012 (Figure 5-19). Phosphorus concentrations at 14237 appear to increase between these two time periods. Station 15048 provided a few phosphorus samples in 2012 with concentrations comparable to those collected at station 14237 in a similar timeframe.



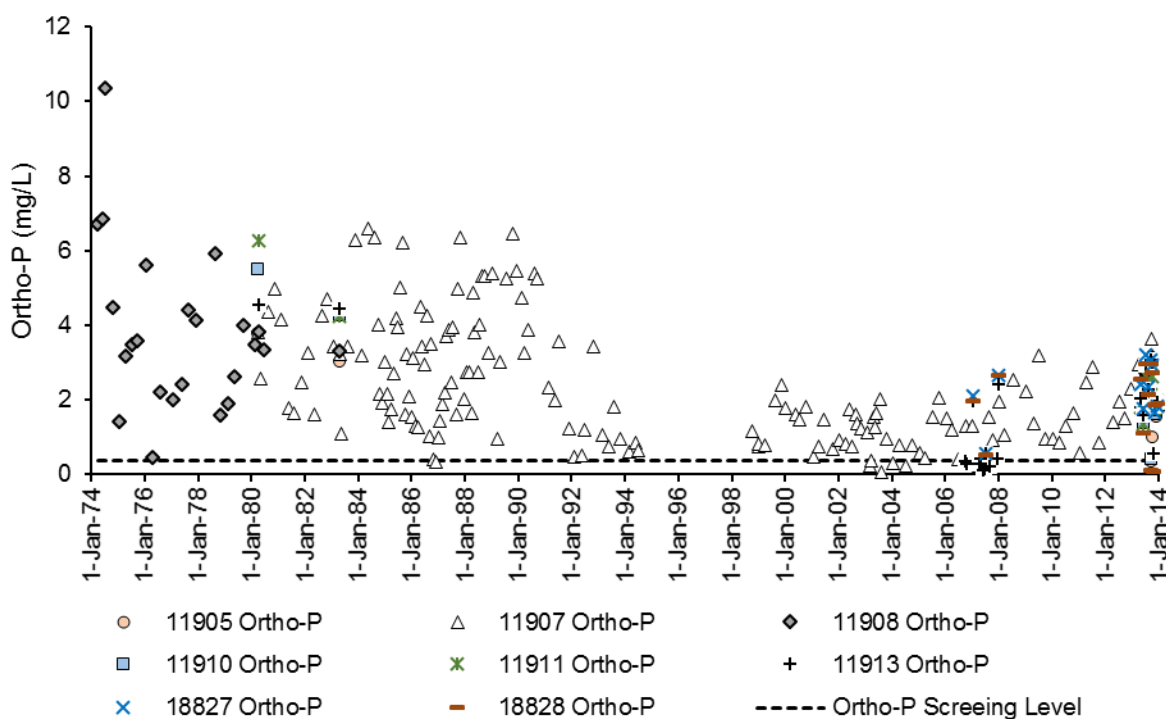
**Figure 5-18** Comparison of ortho-P for two different parameter codes with total-P concentrations for total-P concentrations of 4.33 mg/L or less.



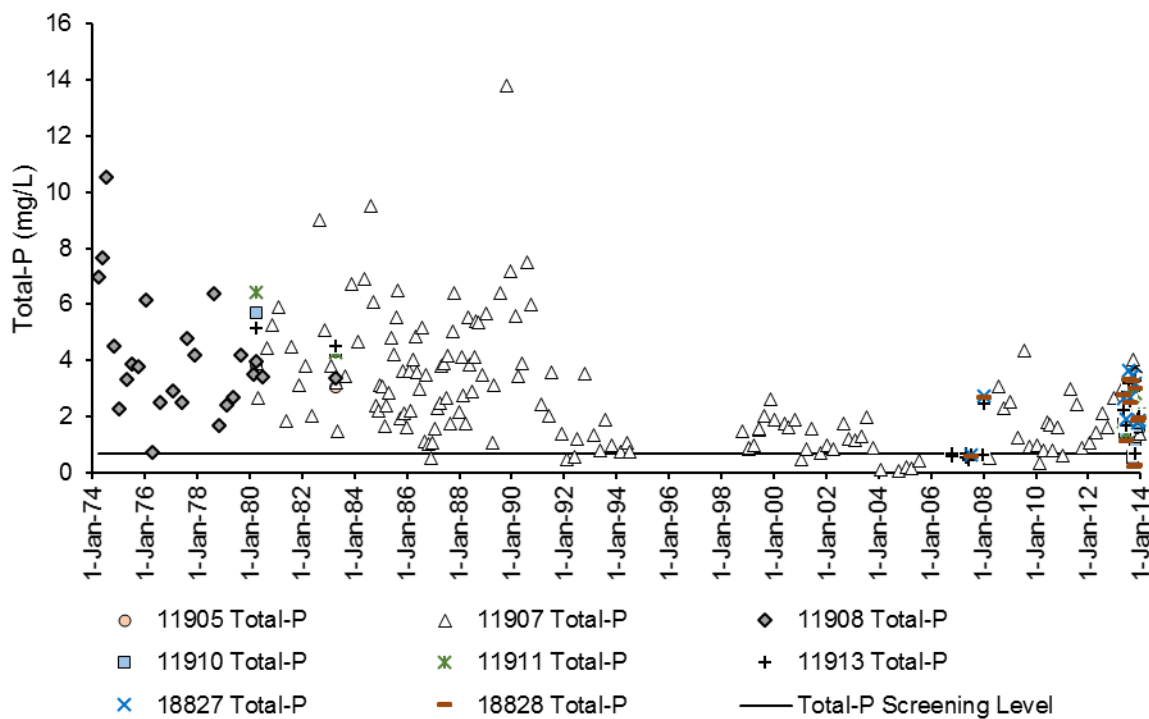
**Figure 5-19** Phosphorus data over time for AU 1218\_01.

Because there are a large number of sampling stations in AU 1218\_02, ortho-P and total-P results are presented in separate graphs (Figure 5-20 and 5-21). Several stations had limited data representing only a few scattered events prior to May 2013. In May 2013 as Phase 2 of this project, monthly monitoring was initiated at eight stations along the mainstem of this AU, thus, leading to a high density on the right-hand end of the temporal scale. Most samples throughout the time history were collected at station 11907, although from 1974 through mid-1980s, station 11908, which is located upstream of 11907, was the primary monitoring location (see Figure 5-1). A notable decrease in phosphorus appears to occur in both ortho-P and total-P starting in the early 1990s (Figures 5-20 and 5-21). This decrease in the early 1990s is likely associated with the phosphorus ban in detergents implemented in Austin, Texas in 1991, which then led to the removal of phosphorus from most laundry detergents sold in Texas (Litke, 1999). In evaluating the data from 1999 through 2013, there is a slight increasing trend in phosphorus concentrations in AU 1218\_02.

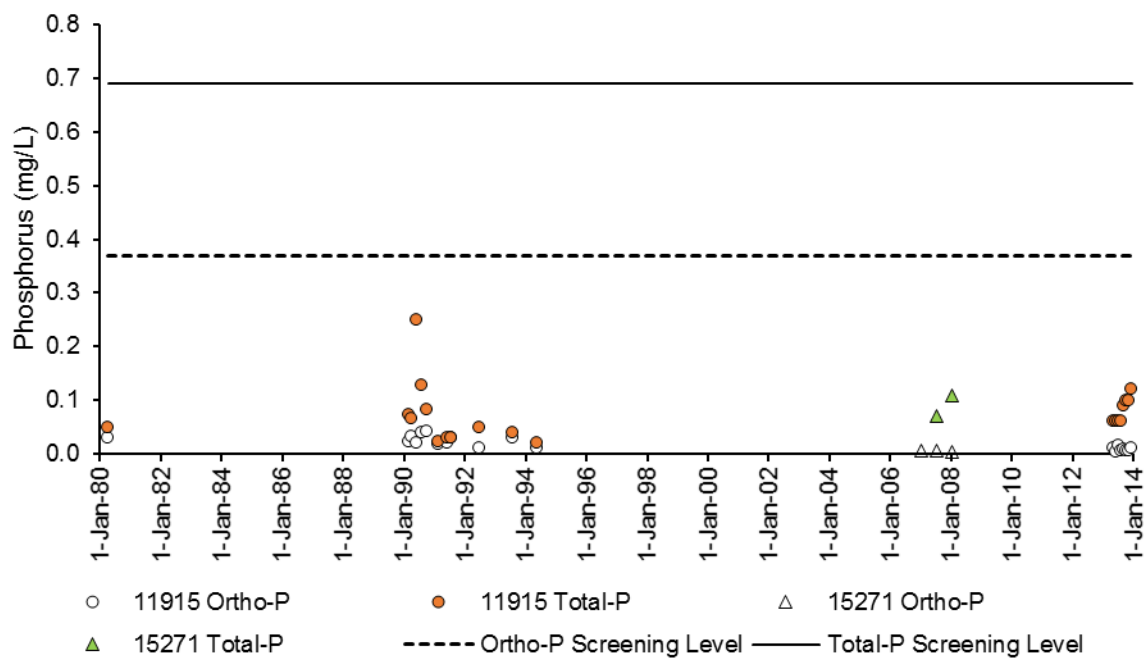
For AU 1218\_03 (Figure 5-22) and 1218B and 1218C (Figure 5-23), phosphorus data were very limited but in all cases well below screening level concentrations. Of note, several of the values for these AUs were noted as below reporting limits (< values) and reported at the reporting limit.



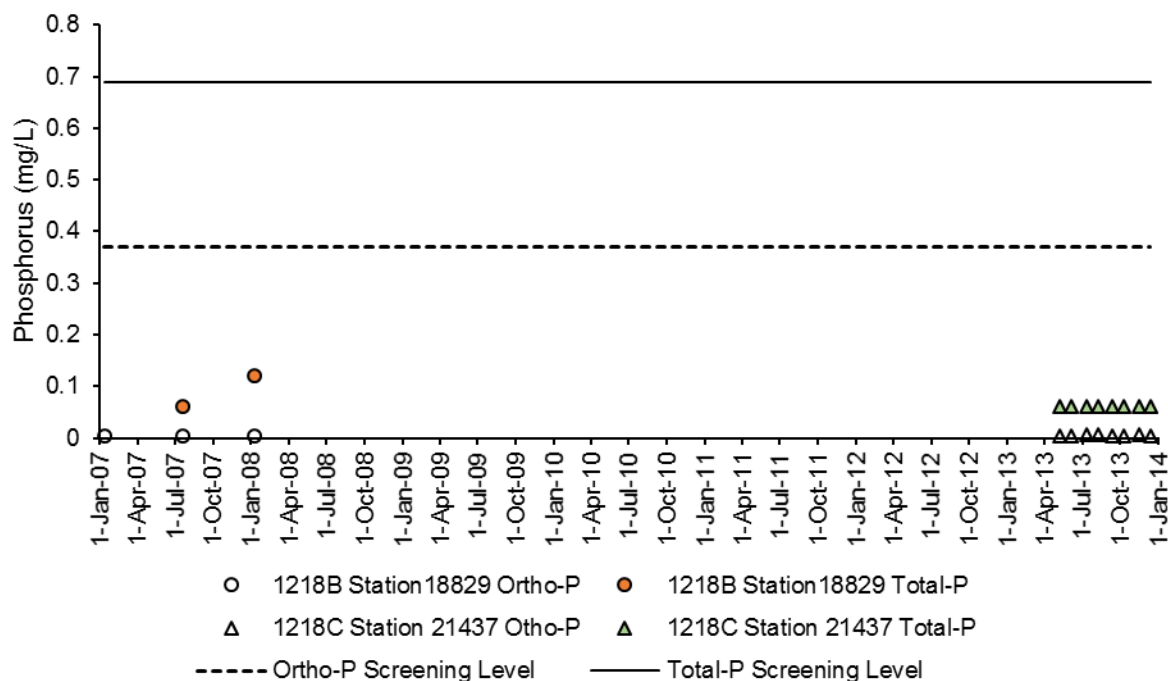
**Figure 5-20** Ortho-P data over time for AU 1218\_02.



**Figure 5-21** Total-P data over time for AU 1218\_02.

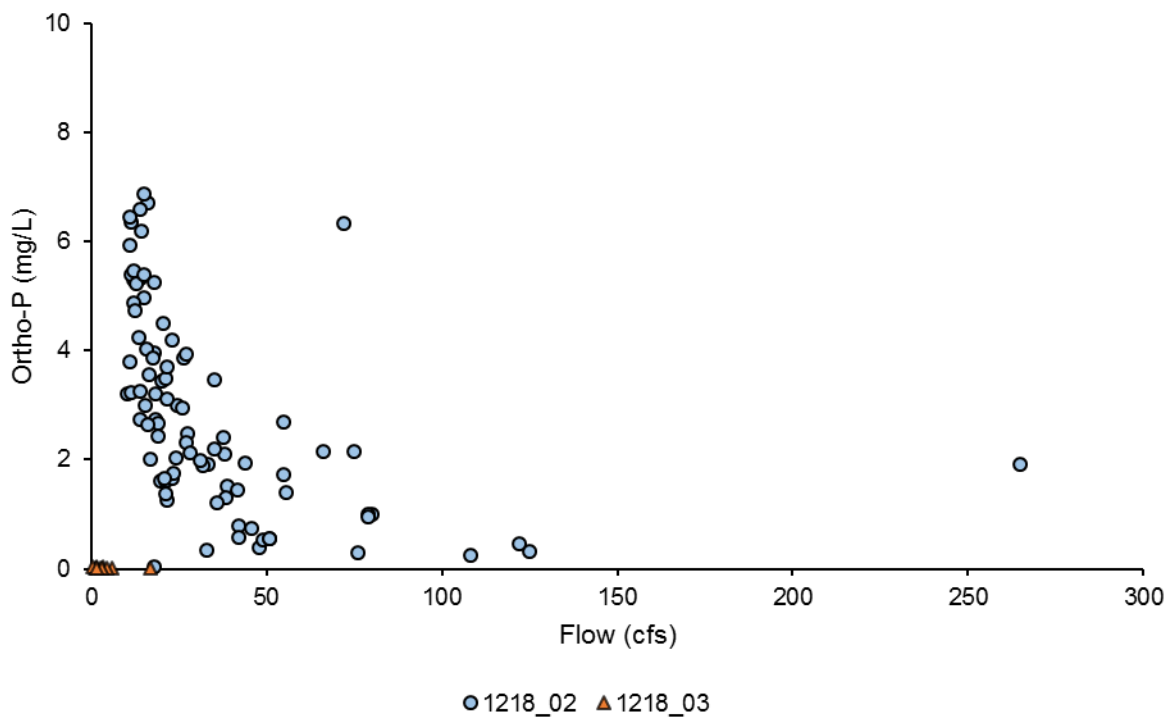


**Figure 5-22** Phosphorus data over time for AU 1218\_03.

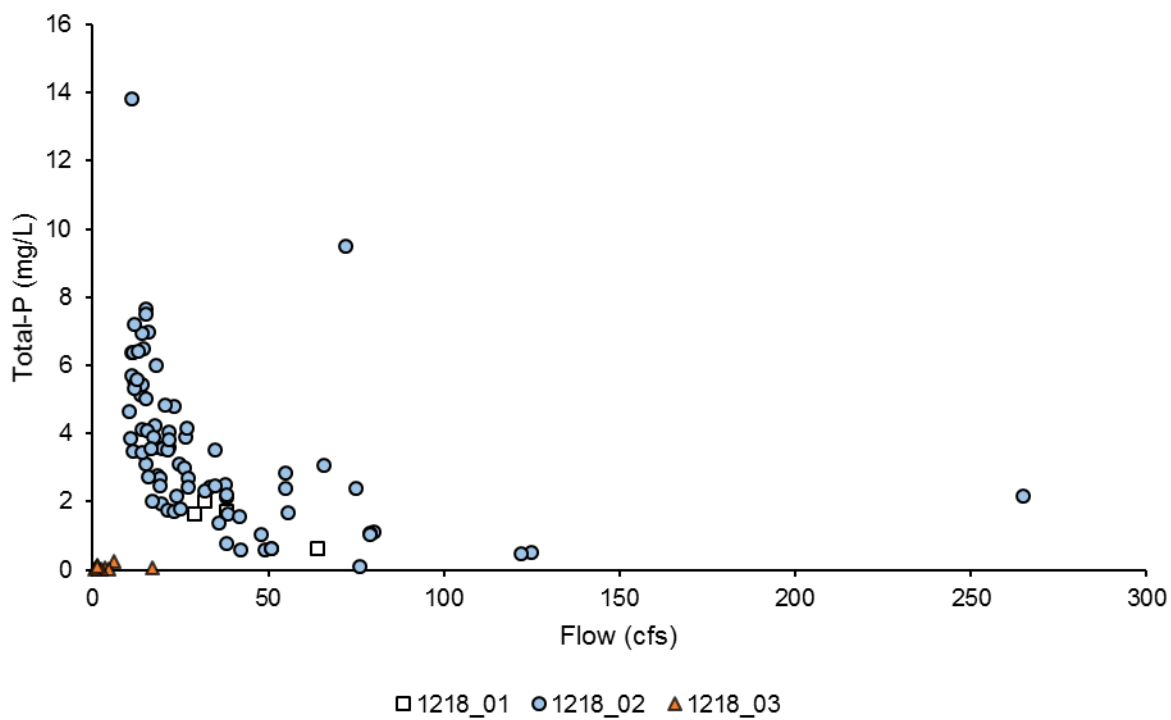


**Figure 5-23** Phosphorus data over time for AU 1218B and 1218C.

In evaluating phosphorus concentrations in relation to flow, about 43 percent of ortho-P observations had paired flow values and 48 percent of total-P observations. Similar to nitrate, but even more pronounced, phosphorus concentrations appeared to decrease with increasing flows for both ortho-P and total-P for paired observations in AUs 1218\_01 and 1218\_03 (Figures 5-24 and 5-25). For AU 1218\_03, only a few paired observations were available that all with low phosphorus concentrations taken at low flows. As with nitrate, the decrease noted in phosphorus concentrations with increasing flows indicates a likely dilution of point source inputs with stormwater runoff.



**Figure 5-24** Flow versus ortho-P concentrations by AU.



**Figure 5-25** Flow versus total-P concentrations by AU.

## Stream Team Volunteer Monitoring

Volunteer monitoring data can be an important component of understanding water quality issues within a watershed and also is a useful tool in engaging stakeholders. The data from volunteers can provide observations at different times and under varying conditions than the professional monitoring network and also can include areas not previously considered, possibly due to costs or manpower considerations. The Texas Stream Team is an organized network of trained volunteers administered through the River Systems Institute at Texas State University in San Marcos, Texas. The Stream Team program is a cooperative partnership between Texas State University, the Texas Commission on Environmental Quality (TCEQ), and the U.S. Environmental Protection Agency (EPA). The Texas Stream Team staff provide training but also maintain a database of the volunteer data collected. Basic training for volunteers includes monitoring of air temperature, specific conductance, pH, and dissolved oxygen. More advanced training includes nitrates and *E. coli*. During the past three years, at least two basic and one advanced training session has occurred drawing participants from the watershed area.

Within the Nolan Creek/South Nolan Creek watershed, there are five active volunteer monitoring sites with varying amounts of data (Table 5-8). At three of these five sites, nitrates and *E. coli* data are collected. Of note, although similar constituents are monitored, the parameter methods used by volunteers are different from those used for data that are submitted to the SWQM database. For example, volunteer bacteria samples have *E. coli* colonies counted using Coliscan Easygel. This does not mean that these data cannot be used, but use of these volunteer data should be tempered by the fact that they involve different methods with less rigorous quality assurance/quality control criteria. In evaluating the Stream Team data for Nolan Creek/South Nolan Creek, average nitrate and geometric mean *E. coli* concentrations appear within the range of values found within the SWQM database, providing some assurance that these data are reasonable in their representation of watershed conditions (Table 5-8).

The Texas Stream Team program promotes monthly monitoring by volunteers and tries to get at least a one year commitment from each volunteer trained. Within or near the Nolan Creek/South Nolan Creek watershed, the Texas Stream Team Staff has conducted at least two basic and one advanced training workshop in the last three years.

**Table 5-8** Location of Texas Stream Team monitoring sites and summary of volunteer monitoring data. Basic observations include air temperature, water temperature, pH, dissolved oxygen, and specific conductance. Advanced observations include nitrate-nitrogen and *E. coli*.

Site	Location	Start Date	End Date	Monitoring Type (Basic or Advanced)	Number of Obs. Basic	Number of Obs. Advanced	Average Nitrate (mg/L)	Geometric Mean <i>E. coli</i> (cfu/100 mL)
80993	South Nolan Creek at HWY 195 and Business 190	3/20/2014	11/19/2014	Advanced	11	11	1.0	163
80680	South Nolan Creek at S W S Young Drive	7/12/2011	11/19/2014	Some Advanced	36	20	1.0	331
80882	Unnamed Tributary of South Nolan Creek downstream of the crossing with Scott and White Drive	10/11/2012	10/26/2014	Some Advanced	15	8	0.8	109
80991	Nolan Creek downstream of HWY 93	11/10/2013	11/10/2013	Basic	1	0	not applicable	not applicable
80891	Nolan Creek near Wall St and Ave C	6/11/2013	8/13/2013	Basic	3	0	not applicable	not applicable

## **SECTION 6**

### **Data Gaps and Data Collection Needed for Source Identification and Load Estimation**

#### **Data Gaps**

One of the purposes of creating this data inventory is to identify data gaps that need to be filled to allow adequate assessment of sources and loadings associated with water quality impairments and concerns in the watershed. The primary focus of this inventory is on data that may aid in addressing bacteria impairments identified for AU 1218\_02 of South Nolan Creek and 1218C for Little Nolan Creek. Nutrient concerns for nitrates, ortho-P, and total-P were also identified in the 2012 Texas Water Quality Inventory for AU 1218\_02. While impairments and concerns from the 2012 Texas Water Quality Inventory were identified only for specific portions of the watershed, data for this inventory were gathered for the full watershed to provide background on the entire area.

In assessing data gaps with regard to data needs associated with running SELECT and developing LDCs, there are a few. For SELECT, the main data gap is in the information available regarding the distribution of OSSFs. Detailed OSSF information is available for the portion of the watershed within the boundaries of the City of Killeen, but will need to be estimated for the rest of the watershed. The distribution of OSSFs for other areas within the watershed can be estimated by overlaying census block data with sewer service areas and assuming all households outside the sewer area are on septic. This likely will underestimate this source, as there are likely households within the sewer areas of the other municipalities also still on septic.

With regard to the water quality data available, some spatial and temporal gaps occur that would hinder the estimation of loadings if based on just these historical data. Most of the water quality data with any temporal consistency has occurred at only a limited number of stations. Although multiple stations have monitoring data within each AU, often individual stations were only monitored for relatively brief time periods. The flow conditions under which monitoring has occurred also has generally favored baseflow conditions limiting the evaluation of point versus nonpoint source conditions. Another item hindering the evaluation of loadings is the limited timeframe of continuous flow data available. The one USGS station provides historical data for almost 10 years from 1974 to 1982, but to derive flow conditions representative of more recent years for loading calculations, hydrologic estimation techniques may be needed, which could involve use of USGS flow gaging stations near but outside the watershed.

To assist in filling the water quality data gaps, Phase 2 of this project addresses direct data collection activities. The direct data collected along with historical data identified in this data inventory as will provide the information needed to estimate loadings and sources in Phase 3, completing the watershed characterization effort for watershed based planning (EPA, 2008). A summary of Phase 2 and Phase 3 activities are provided below. As completed, separate reports will document the details of the findings from these two phases.

## Direct Data Collection

For Phase 2, a water quality monitoring plan was developed that is included as an appendix to the project's monitoring quality assurance project plan (QAPP). Direct monitoring includes monthly grab sampling at 11 locations and quarterly storm monitoring at 4 locations as identified in Table 5-4. While storm monitoring is important in assessing nonpoint source contributions, due to cost considerations and the often unpredictable nature of storm runoff, only a limited amount of storm monitoring was included in this project to allow some characterization of bacteria concentrations and loadings under a variety of flow conditions for use in development of load duration curves (Phase 3). Storm sampling stations include an automated sampler and a flow meter allowing continuous recording of water level.

Monthly monitoring parameters will include *E. coli*, nitrate, ortho-P, total P, total Kjeldahl nitrogen (TKN), and total suspended solids (TSS). Sonde data including dissolved oxygen (DO), specific conductance (conductivity), pH, and water temperature will also be collected with monthly grab samples. Instantaneous flow will also be measured the same day as each grab sample, if conditions allow. During elevated flows, safety and access issues may preclude the measurement of flow at some locations.

Storm sampling stations include an automated sampler set to initiate upon a selected rise in water level and a flowmeter to continuously record stream water levels. Storm samples for nutrients and TSS will focus on the first flush of an event and will be collected by the automated sampler. A storm grab for analysis of *E. coli* is collected when the automated sampler samples are retrieved. Storm samples collected by the automated sampler are flow composited over the first portion of each event and analyzed for the same nutrient parameters as routine grab samples as well as TSS.

Because water quality assessments focus on routine monitoring data, monitoring is focused on routine grab sampling, a goal being that the data collected would be suitable for use in future assessment by TCEQ of Segment 1218 that could potentially lead to delisting. While most of Texas, including the watershed area of the Nolan Creek/South Nolan Creek, has been under drought conditions for the last few years, the Nolan Creek/South Nolan Creek generally has perennial flow throughout, in part due to discharge contributions from WWTFs associated with the cities of Killeen, Harker Heights, Nolanville, and Belton and portions of Fort Hood. Of note, discharge from the WWTF associated with the City of Belton is located near the bottom of the watershed near the confluence of Nolan Creek with the Leon River, thus, has no impact on the water quality along South Nolan or along most of Nolan Creek. We anticipate that routine monthly monitoring continue under a variety of flow conditions allowing in conjunction with storm monitoring the ability to access bacteria and nutrient concentrations under a broad range of flow conditions. More specifics regarding the direct monitoring associated with this project can be found in the project's monitoring QAPP.

## Source Identification and Load Estimation

As Phase 3 of the watershed characterization process as outlined for this project, sources and potential sources and the potential bacteria contributions by each source will be identified by sub-watershed using the Spatially Explicit Load Enrichment Calculation Tool (SELECT). The

Spatial Sciences Laboratory (SSL) and the Biological and Agricultural Engineering Department at Texas A&M University (TAMU) developed SELECT as a screening model to calculate contaminant-loads resulting from various sources in a watershed that spatially references these loadings via an ArcGIS environment (Teague et al., 2009). This data inventory provides the inputs needed for SELECT as SELECT requires a thorough characterization of the land uses within the watershed as well as information on the population density of people, livestock, pets, and wildlife.

To estimate loadings and load reductions needed, load duration curves (LDCs) will be developed for at least four locations within the watershed. Load Duration Curves are a simple and an effective first-step methodology to obtain loadings under varying flow regimes (EPA, 2007; Cleland, 2003). A duration curve is a graph that illustrates the percentage of time during which a given parameter's value is equaled or exceeded. For example, a FDC uses the hydrograph of the observed or estimated stream flows to calculate and depict the percentage of time a given flow is equaled or exceeded. A LDC, which is related to the FDC, shows the corresponding relationship between the contaminant loadings and stream flow conditions at the monitoring site. In this manner, it assists in determining patterns in pollution loading (point sources, nonpoint sources, erosion, etc.) depending on the streamflow conditions.

These LDCs will be developed using historical data and additional project-collected data focusing on the four storm monitoring stations identified in Table 5-4. The continuous stream level data collected at these four stations will be used to aid in estimating historical flows as outlined in the project modeling QAPP. Based on the observed patterns, needed loading reductions can be estimated for target or criterion levels associated with water quality restoration (EPA, 2007).

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## Appendix A

### Unauthorized Discharges

**Table A-1** Unauthorized discharges within the Nolan Creek/South Nolan Creek, set 1 of information provided by TCEQ from open records request.

Name of Regulated Entity	Complaint Incident Start Date	Complaint Notification Date Received	Comment Type	Comments	Material	Amount	Incident Cause
City of Harker Heights WWTP	02/17/2004	02/23/2004	DESC	Man hole behind #10 Lift Station at 420 Robinson Lane, line blockage.	Wastewater discharge, municipal	300	Other
City of Harker Heights WWTP	02/17/2004	02/23/2004	COMMENT	Grease and trash stuck together formed blockage. It was cleaned out.	Wastewater discharge, municipal	300	Other
City of Harker Heights WWTP	02/17/2004	02/23/2004	ACTION	Area around manhole disinfected with bleach. Used vacuum truck to clean out sewer line. Blocked line about 100 ft inside line. Ran line from manhole at #10 lift toward manhole that was overflowing.	Wastewater discharge, municipal	300	Other
City of Harker Heights WWTP	06/28/2004	08/26/2004	DESC	Manhole upstream from Wildwood Lift station flowing into drainage ditch. Cause: manhole in new subdivision left with lid off.	Wastewater discharge, municipal	1,575	Other
City of Harker Heights WWTP	06/28/2004	08/26/2004	ACTION	Unable to mitigate until 06/29/04 due to heavy duration of rainfall and subsequent storm water runoff in drainage ditch. Developer ordered to seal manhole.	Wastewater discharge, municipal	1,575	Other

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Name of Regulated Entity	Complaint Incident Start Date	Complaint Notification Date Received	Comment Type	Comments	Material	Amount	Incident Cause
City of Harker Heights WWTP	08/27/2004	02/02/2005	DESC	Collection line possibly collapsed, sewage flowing into drainage ditch.	Wastewater discharge, municipal	800	Other
City of Harker Heights WWTP	08/27/2004	02/02/2005	ACTION	Fixed collapsed line.	Wastewater discharge, municipal	800	Other
City of Harker Heights WWTP	01/01/1800	11/04/2009	DESC	Bell County: The City of Harker Heights reported an unauthorized discharge of wastewater from manhole #117 on North Amy. The discharge began at 8:00 am on October 22 and ended at 17:00 pm on October 22. The cause of the discharge was due to excessive rain. The discharge was estimated to be about 240,000 gallons.	Wastewater discharge, municipal	240,000	Other
City of Harker Heights WWTP	09/08/2010	10/08/2010	DESC	Bell County: Beginning on 9/7/2010 and continuing on 9/8/2010 the City of Harker Heights received 11.5 "of rain from Tropical Storm Hermine. This event caused Nolan Creek to leave its bank and flood the WWTP, VFW and Tonight lift stations.	Sewage	0	Equipment Failure
City of Harker Heights WWTP	09/08/2010	10/08/2010	ACTION	WWTP was running on emergency generator power for the extended period. The plant has been cleaned up from the flooding and is operating per design under normal power. Ensured the UV is operating	Sewage	0	Equipment Failure

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218

Name of Regulated Entity	Complaint Incident Start Date	Complaint Notification Date Received	Comment Type	Comments	Material	Amount	Incident Cause
				correctly and monitor the plant closely.			
City of Harker Heights WWTP	03/20/2012	04/13/2012	DESC	The cause of the overflow was due to 5 inches of rain received within a 24 hour period.	Sewage	4,200	Other
City of Harker Heights WWTP	03/20/2012	04/13/2012	ACTION	Cleaned and disinfected the area with 70/30 bleach mixture and vacuumed. Will monitor area more closely to prevent any further mishaps.	Sewage	4,200	Other
City of Harker Heights WWTP	03/20/2012	04/18/2012	DESC	The cause of the overflow was due to 5 inches of rain within a 24 hour period.	Sewage	4,500	Other
City of Harker Heights WWTP	03/20/2012	04/18/2012	ACTION	Cleaned and disinfected the area with 70/30 bleach mixture and vacuumed the area. Will monitor area more closely to prevent any further mishaps.	Sewage	4,500	Other
City of Harker Heights WWTP	03/20/2012	04/18/2012	DESC	The cause of the overflow was due to 5 inches of rain within a 24 hour period at 811 Roy Reynolds.	Sewage	4,200	Other
City of Harker Heights WWTP	03/20/2012	04/18/2012	ACTION	Cleaned and disinfected the area with 70/30 bleach mixture and vacuumed the area. Will monitor area more closely to prevent any further mishaps.	Sewage	4,200	Other
City of Harker Heights WWTP	03/20/2012	04/18/2012	DESC	Excessive rain cause a manhole to overflow onto the ground at N. Amy.	Sewage	9,300	Other
City of Harker Heights WWTP	03/20/2012	04/18/2012	ACTION	Cleaned and disinfected the area with 70/30 bleach mixture and vacuumed the area. Will	Sewage	9,300	Other

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218

Name of Regulated Entity	Complaint Incident Start Date	Complaint Notification Date Received	Comment Type	Comments	Material	Amount	Incident Cause
				monitor area more closely to prevent any further mishaps.			
City of Harker Heights WWTP	03/20/2012	04/18/2012	DESC	Excessive rain caused a manhole to overflow on ground at Pecan Street.	Sewage	4,200	Other
City of Harker Heights WWTP	03/20/2012	04/18/2012	ACTION	Cleaned and disinfected the area with 70/30 bleach mixture and vacuumed the area. Will monitor area more closely to prevent any further mishaps.	Sewage	4,200	Other
City of Harker Heights WWTP	03/20/2012	04/18/2012	DESC	Excessive rain caused private cleanout to overflow on to ground at 809 Roy Reynolds.	Sewage	4,200	Other
City of Harker Heights WWTP	03/20/2012	04/18/2012	ACTION	Cleaned and disinfected the area with 70/30 bleach mixture and vacuumed the area. Will monitor area more closely to prevent any further mishaps.	Sewage	4,200	Other
City of Harker Heights WWTP	03/20/2012	04/18/2012	DESC	Excessive rain caused a manhole 01MH 012TP to overflow on to ground at North Amy.	Sewage	37,200	Other
City of Harker Heights WWTP	03/20/2012	04/18/2012	ACTION	Cleaned and disinfected the area with 70/30 bleach mixture and vacuumed the area. Will monitor area more closely to prevent any further mishaps.	Sewage	37,200	Other
City of Harker Heights WWTP	03/20/2012	04/18/2012	DESC	Excessive rain caused private cleanout to overflow on to ground at 805 Roy Reynolds.	Sewage	4,200	Other
City of Harker Heights WWTP	03/20/2012	04/18/2012	ACTION	Cleaned and disinfected the area with 70/30 bleach mixture and vacuumed the area. Will monitor area more closely to prevent any further mishaps.	Sewage	4,200	Other

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218

Name of Regulated Entity	Complaint Incident Start Date	Complaint Notification Date Received	Comment Type	Comments	Material	Amount	Incident Cause
City of Harker Heights WWTP	04/04/2012	04/18/2012	DESC	Approximately 200 gallons of raw sewage flowed on to the ground from 17 mh 213-14 behind 2000 Drawbridge.	Sewage	200	Equipment Failure
City of Harker Heights WWTP	04/04/2012	04/18/2012	ACTION	Vacuumed the standing water, cut section of SDR35 pipe and attached and disinfected area.	Sewage	200	Equipment Failure
City of Harker Heights WWTP	04/12/2012	05/24/2012	DESC	An overflow of 200 gallons due to a broken main at manhole 387.	Sewage	200	Equipment Failure
City of Harker Heights WWTP	04/12/2012	05/24/2012	ACTION	Vacuumed the standing water, cut section of SDR35 pipe and attached with 2 non shear boots, and disinfected area.	Sewage	200	Equipment Failure
City of Harker Heights WWTP	09/26/2012	10/09/2012	DESC	Estimated 2 gallons of raw sewage flowed into a dry creek bed from a private sewer line at 111 E. Ball St.	Sewage	2	Other
City of Harker Heights WWTP	09/26/2012	10/09/2012	ACTION	Operators cleaned up the sewer and disinfected the area with 70/30 bleach solution. Code enforcement was notified and has started procedures to turn off their water until the landlord makes arrangements to fix the problem.	Sewage	2	Other
City of Harker Heights WWTP	08/17/2012	10/09/2012	DESC	The force main was leaking at 303 W. Central Texas Expressway			
City of Harker Heights WWTP	08/17/2012	10/09/2012	ACTION	Crews excavated the area cut out damaged pipe put in section and fastened it together with 2 fernco non sheer boots.			

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218

Name of Regulated Entity	Complaint Incident Start Date	Complaint Notification Date Received	Comment Type	Comments	Material	Amount	Incident Cause
City of Harker Heights WWTP	08/16/2012	10/09/2012	DESC	An estimated 50 gallons of raw sewage seeped through a crack at 303 W. Central Texas Expressway. The sewage appeared to be coming from a force main.	Sewage	50	Other
City of Harker Heights WWTP	08/16/2012	10/09/2012	ACTION	Crews are on the site and preparing the area for excavation in order to repair the problem. The vacuum truck was sent to the area to clean up all sewer and disinfect with a bleach and water solution	Sewage	50	Other
City of Harker Heights WWTP	09/10/2012	10/09/2012	DESC	An estimated 20 gallons of raw sewage overflowed onto the ground from the city cleanout 06-mh 326-tp to city cleanout 06-co 327-tp.	Sewage	20	Other
City of Harker Heights WWTP	09/10/2012	10/09/2012	ACTION	Jetted line from the 06-mh 326-tp to city cleanout 06-co 327-tp. Cleaned and disinfected area with 70/30 bleach solution. Installed cleanout plug and replaced the brass cleanout cap.	Sewage	20	Other
City of Harker Heights WWTP	08/24/2012	10/09/2012	DESC	An estimated 25 gallons of raw sewage overflowed onto the ground from a manhole at 1003 Old Oaks Dr.	Sewage	25	Other
City of Harker Heights WWTP	08/24/2012	10/09/2012	ACTION	Jetted line with vector, vacuumed area, and disinfected the area with 70/30 bleach mixture.	Sewage	25	Other
City of Harker Heights WWTP	05/31/2011	10/09/2012	DESC	An estimated 700 gallons of raw sewage overflowed onto the ground from 05-mh 435-tp and	Sewage	700	Other

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218

Name of Regulated Entity	Complaint Incident Start Date	Complaint Notification Date Received	Comment Type	Comments	Material	Amount	Incident Cause
				05-mh located 200 feet southwest behind 126 Beeline Street in the field.			
City of Harker Heights WWTP	05/31/2011	10/09/2012	ACTION	Jetted line with vactor, vacuumed up sewage off the ground, and disinfected the area with 70/30 bleach solution.	Sewage	700	Other
Temple/Belton Regional WWTP	10/02/2014	10/29/2014	DESC	Hickory lift station wet weather overflow. Cause: Severe weather on October 2, 2014, resulting in power outage at lift station. Actions taken: BRA received no power call at 10:30 PM and hauled portable generator to lift station. Power restored with generator 11:55pm. BRA also called S&S Vacuum trucks to assist and clean up site as needed.	Sewage	10,000	Act of God

**Table A-2** Unauthorized discharges within the Nolan Creek/South Nolan Creek, set 2 of information provided by TCEQ from open records request.

Customer Name	Start Date	End Date	Volume (gallons)	Incident Source Name	Location
City of Belton and City of Temple	26-Nov-11	26-Nov-11	1500	Manhole	Burnet St + Ave B
Bell County WCID #3	25-Jan-12	25-Jan-12	1000	WWTP	389 Waterworks Rd
City of Belton and City of Temple	26-Feb-12	26-Feb-12	100	Manhole	Ave A + Davis St
City of Harker Heights	10-Feb-13	10-Feb-13	95	Manhole	Cagle + Harley
City of Harker Heights	22-Feb-13	25-Feb-13	No data	Manhole	557 W Veterans Memorial Blvd
City of Harker Heights	6-Mar-13	6-Mar-13	30	Private Cleanout	1411 Mogican Trail
Bell County WCID 1	20-May-13	20-May-13	135	Manhole	1406 E Ave G
City of Harker Heights	21-May-13	21-May-13	250	Manhole	515 Clore
City of Harker Heights	27-Jun-13	27-Jun-13	200	Cleanout	1101 Bluebird
City of Harker Heights	15-Jul-13	15-Jul-13	500	Cleanout	809 Roy Reynolds
City of Harker Heights	15-Jul-13	15-Jul-13	500	Cleanout	811 Roy Reynolds
City of Harker Heights	16-Jul-13	17-Jul-13	300	Cleanout	811 Roy Reynolds

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218

<b>Customer Name</b>	<b>Start Date</b>	<b>End Date</b>	<b>Volume (gallons)</b>	<b>Incident Source Name</b>	<b>Location</b>
City of Harker Heights	22-Jul-13	22-Jul-13	40	Manhole	234 East Cardinal
City of Harker Heights	6-Aug-13	6-Aug-13	5	Air Relief Valve	Vintage Way Cul-de-Sac
City of Harker Heights	16-Sep-13	16-Sep-13	10	Cleanout	1103 and 1105 Bluebird
City of Harker Heights	21-Sep-13	21-Sep-13	80	Manhole	202 Pomo Trail
City of Harker Heights	12-Nov-13	12-Nov-13	10	Manhole	400 Randy
City of Harker Heights	26-Nov-13	26-Nov-13	50	Manhole	1001 Old Oak
City of Harker Heights	14-Dec-13	14-Dec-13	75	Manhole	Dale Earnhardt
City of Killeen	16-Dec-13	17-Dec-13	1230	Manhole	
City of Killeen	16-Dec-13	16-Dec-13	1125	Manhole	2400 EVMB
City of Killeen	18-Dec-13	18-Dec-13	1490	Manhole	2400 EVMB
City of Killeen	28-Dec-13	28-Dec-13	275	Manhole	Conder & VMB
City of Killeen	30-Dec-13	30-Dec-13	900	Manhole	2400 EVMB
City of Killeen	10-Jan-14	10-Jan-14	440	Manhole	2204 Corona Dr
City of Killeen	11-Jan-14	11-Jan-14	2800	Manhole	4011 Madison Dr
City of Harker Heights	12-Jan-14	12-Jan-14	150	Manhole	226 East Cardinal
City of Harker Heights	20-Jan-14	20-Jan-14	100	Manhole	224 East Cardinal

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218

<b>Customer Name</b>	<b>Start Date</b>	<b>End Date</b>	<b>Volume (gallons)</b>	<b>Incident Source Name</b>	<b>Location</b>
City of Harker Heights	31-Jan-14	31-Jan-14	150	Cleanout	108 East Stacie
City of Harker Heights	31-Jan-14	31-Jan-14	150	Cleanout	108 West Stacie
City of Harker Heights	18-Feb-14	19-Feb-14	300	Cleanout	1751A Verna Lee
City of Harker Heights	20-Feb-14	20-Feb-14	150	Manhole	226 East Cardinal
City of Harker Heights	19-Mar-14	19-Mar-14	150	Cleanout	1715B Verna Lee
City of Harker Heights	19-Mar-14	19-Mar-14	5500	Air Relief Valve	Field West of Kachina Loop
City of Harker Heights	25-Mar-14	26-Mar-14	150	Cleanout	2301 Indian Trail
City of Harker Heights	4-Apr-14	4-Apr-14	50	Manhole	2132 Modoc
City of Harker Heights	8-Apr-14	8-Apr-14	30	Manhole	cul-de-sac of Vineyard towards Chaparral
Bell County WCID 1	8-May-14	8-May-14		Manhole	1407 Ave G, Killeen, TX
City of Harker Heights	15-May-14	15-May-14	150	Manhole	1220 Preswick Circle
City of Harker Heights	5-Jun-14	5-Jun-14	70	Cleanout	Pleasant View Mobile Home Park 305 S. Amy Lane

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218

<b>Customer Name</b>	<b>Start Date</b>	<b>End Date</b>	<b>Volume (gallons)</b>	<b>Incident Source Name</b>	<b>Location</b>
City of Harker Heights	10-Jun-14	10-Jun-14	2000	WWTP	430 Pecan
City of Harker Heights	18-Jun-14	18-Jun-14	200	Service Line	218 E Valley
City of Harker Heights	19-Jun-14	19-Jun-14	150	Manhole	706 Edwards Drive
City of Harker Heights	19-Jun-14	19-Jun-14	50	Service Line	Drainage ditch on Mountain Lion near Modoc
City of Harker Heights	24-Jun-14	24-Jun-14	50	Service Line	302 E Elbert
City of Harker Heights	24-Jun-14	24-Jun-14	50	Service Line	111 Cox Dr
City of Harker Heights	26-Jun-14	26-Jun-14	35	Manhole	101 Evergreen Dr.
City of Harker Heights	21-Jul-14	21-Jul-14	10	Sewer Main	777 Indian Trail
City of Harker Heights	1-Aug-14	1-Aug-14	50	Manhole	226 East Cardinal
Bell County WCID 1	5-Aug-14	5-Aug-14	60	Manhole	Fort Hood, Building 21008
City of Harker Heights	7-Aug-14	8-Aug-14	100	Manhole	839 Buffalo
City of Harker Heights	20-Aug-14	21-Aug-14	50	Manhole	710 Edwards
City of Harker Heights	31-Aug-14	31-Aug-14	150	Manhole	210 Dale Earnhardt

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218

<b>Customer Name</b>	<b>Start Date</b>	<b>End Date</b>	<b>Volume (gallons)</b>	<b>Incident Source Name</b>	<b>Location</b>
City of Harker Heights	17-Sep-14	17-Sep-14	2	Private Cleanout	904 B Rebecca
City of Harker Heights	17-Sep-14	17-Sep-14	100	Manhole	Harley and Dove Lane Intersection
City of Harker Heights	18-Sep-14	18-Sep-14	100	Manhole	Intersection of Harley and Dove Lane
City of Harker Heights	26-Sep-14	26-Sep-14	150	Manhole	700 Indian Trail
City of Harker Heights	10-Oct-14	10-Oct-14	15	Cleanout	2001 Indian Trail Lot #66
City of Harker Heights	13-Oct-14	13-Oct-14	150	Cleanout	1601 Harley
City of Harker Heights	15-Oct-14	15-Oct-14	10	Manhole	801 Terra Cotta Ct
City of Harker Heights	15-Oct-14	15-Oct-14	500	Air Relief Valve	960 FM 2410
City of Harker Heights	17-Oct-14	17-Oct-14	1500	Manhole	4100 E Veterans Memorial Blvd
City of Harker Heights	20-Oct-14	20-Oct-14	50	Cleanout	2001 Indian Trail Lot #66
City of Harker Heights	27-Oct-14	27-Oct-14	50	Cleanout	1101 Bluebird
City of Killeen	5-Nov-14	5-Nov-14	470	Service Line	817 VMB
City of Killeen	5-Nov-14	5-Nov-14	470	Service Line	817 VMB
City of Harker Heights	12-Nov-14	12-Nov-14	300	Service Line	937 Ashwood
City of Harker Heights	12-Nov-14	12-Nov-14	300	Service Line	937 Ashwood
City of Harker Heights	14-Nov-14	14-Nov-14	1500	Service Line	521 E Veterans Memorial Blvd

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218

<b>Customer Name</b>	<b>Start Date</b>	<b>End Date</b>	<b>Volume (gallons)</b>	<b>Incident Source Name</b>	<b>Location</b>
City of Harker Heights	14-Nov-14	14-Nov-14	700	Service Line	430 Pecan Dr
City of Killeen	18-Nov-14	18-Nov-14	90	Service Line	3404 Victoria Circle
City of Killeen	20-Nov-14	20-Nov-14	5	Manhole	2400 EVMB
City of Killeen	21-Nov-14	21-Nov-14	8	Manhole	3702 Frigate
City of Killeen	26-Nov-14	26-Nov-14	371	Manhole	Tripp Trail and Sherman
City of Killeen	3-Dec-14	3-Dec-14	120	Manhole	1410 Greenwood
City of Harker Heights	6-Dec-14	6-Dec-14	200	Service Line	Vicinity of McDonalds & Valero gas station
City of Harker Heights	7-Dec-14	7-Dec-14	250	Cleanout	805 Roy Reynolds Rd

## Appendix B

### Reported Fish Kills

**Table A-1** Unauthorized discharges within the Nolan Creek/South Nolan Creek based on information obtained from TCEQ open records request for data between 2004 and 2013.

Event ID	Location	Start Date	Est. Total Killed	General Source	Specific Source	General Cause	Specific Cause	Source Action
19972A771	Nolan Creek - from Amy Lane upstream to approximately 56th-58th Streets.	3/28/1972		Municipal (Confirmed)	Wastewater Treatment Plant (Confirmed)	Organic Compound (Confirmed)	Sewage (Confirmed)	Unpermitted Discharge (Confirmed)
19972A772	Nolan Creek - above and below Belton sewage treatment plant	8/14/1972	15	Individual (Suspected)	Recreational Fishing (Suspected)	Organic Compound (Suspected)	Rotenone (Suspected)	Unpermitted Discharge (Suspected)
19972A774	Nolan Creek - at 99 FM 2271	3/6/1976	175	Municipal (Suspected)	Wastewater Treatment Plant (Suspected)	Organic Compound (Suspected)	Sewage (Suspected)	Unpermitted Discharge (Suspected)
19972A770	Nolan Creek - at Dimple Street in Killeen, Texas	5/17/1977	1764	Municipal (Confirmed)	Sewer Lines (Confirmed)	Inorganic Compound (Confirmed)	Chlorine (Confirmed)	Unpermitted Discharge (Confirmed)
19972A767	North Nolan Creek - upstream from FM 439 to pipeline crossing	1/13/1983	81	Municipal (Confirmed)	Sewer Lines (Confirmed)	Inorganic Compound (Confirmed)	Chlorine (Confirmed)	Spill (Confirmed)

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218

Event ID	Location	Start Date	Est. Total Killed	General Source	Specific Source	General Cause	Specific Cause	Source Action
19972A754	Little Nolan Creek - private pond on a tributary in Harker Heights	8/18/1987		Municipal (Confirmed)	Housing Area, General (Suspected)	Inorganic Compound (Suspected)	Fertilizer (Suspected)	Excess Addition of Nutrients (Confirmed)
19912M693	Nolan Creek - below Belton	8/14/1989		Individual (Suspected)	Unpermitted Dumping (Suspected)	Organic Compound (Suspected)	Other (Suspected) -- Note: Contaminant = pollution in general, Conductivity of 681 umhos/cm	Other (Suspected)
19952M442	South Nolan Creek - Harker Heights lift station downstream for about 2 miles	10/31/1995		Municipal (Confirmed)	Wastewater Treatment Plant (Confirmed)	Low Dissolved Oxygen (Confirmed)	Sewage Bypass (Confirmed)	Unpermitted Discharge (Confirmed)
19962M542	Central Texas College - front pond in Killeen, Texas	7/23/1996	140	Natural Process (Confirmed)	Other Physiological Stress (Confirmed)	Low Dissolved Oxygen (Confirmed)	Algal Respiration (Confirmed)	Reduced Flow (Confirmed)
19972A1385	South Nolan Creek - both Backstrom Crossing Bridges	9/12/1997	1991	Municipal (Confirmed)	Water Lines (Confirmed)	Inorganic Compound (Confirmed)	Chlorine (Confirmed)	Spill (Confirmed)
19972A1390	South Nolan Creek - from just above Levy Crossing to	9/28/1997	2194	Municipal (Confirmed)	Sewer Lines (Confirmed)	Inorganic Compound (Confirmed)	Chlorine (Confirmed)	Spill (Confirmed)

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218

Event ID	Location	Start Date	Est. Total Killed	General Source	Specific Source	General Cause	Specific Cause	Source Action
	below Highway 190							
19992A7344	Nolan Creek-from Harker Heights to second crossing of Paddy Hamilton Road	7/26/1999	6245	Municipal (Confirmed)	Water Lines (Confirmed)	Pollutant (Confirmed)	Chlorine (Confirmed)	Spill (Confirmed)
20012A8056	Pond - Central Texas College, Killeen, Texas	10/6/2000	800	Natural Process (Confirmed)	Algal Bloom (Confirmed)	Low Dissolved Oxygen (Confirmed)	Algal Respiration (Confirmed)	Excess Addition of Nutrients (Confirmed)
20022A8550	Nolan Creek - at Hwy 190 and FM 195	6/21/2002		Municipal (Confirmed)	Sewer Lines (Confirmed)	Pollutant (Confirmed)	Sewage (Confirmed)	Spill (Confirmed)
20072A705	5505 Creekside Dr. Killeen, Tx	4/12/2003	100	Municipal (Confirmed)	Sewer Lines (Confirmed)	Pollutant (Confirmed)	Sewage (Confirmed)	Spill (Confirmed)
20072A718	1803 Fairway Dr., Killeen, TX 76549	6/10/2003	25	Natural Processes (Suspected)	Disease (Suspected)	Disease (Suspected)	Bacteria/Virus (Suspected)	Natural Processes (Suspected)
20072A791	Nolan Creek - Killeen, Tx	9/18/2003		Natural Process (Confirmed)	Algal Bloom (Confirmed)	Color/Scum/Foam (Confirmed)	Algal Bloom (Confirmed)	Natural Processes (Confirmed)
20072A863	Tributary of Trimmier Creek - 4812 Acorn Creek Trl -Killeen, TX 76542	8/15/2004	3	Municipal (Confirmed)	Water Lines (Confirmed)	Pollutant (Confirmed)	Chlorine (Confirmed)	Spill (Confirmed)

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218

Event ID	Location	Start Date	Est. Total Killed	General Source	Specific Source	General Cause	Specific Cause	Source Action
20072A872	S. Nolan River - Killeen, TX	12/8/2004		Industry, Other (Confirmed)	Military (Confirmed)	Other (Confirmed)	Other (Suspected) -- Contaminant = Dechlorinated Water	Unregulated Discharge (Confirmed)
20062A151	S. Nolan Creek - Killeen, TX	2/6/2006	100	Municipal (Confirmed)	Sewer Lines (Confirmed)	Pollutant (Confirmed)	Sewage (Confirmed)	Spill (Confirmed)
20072A8831	S.Nolan Creek - e. Highway 201 at bridge near Killeen/Ft. Hood Airport, Killeen, TX	10/29/2007		Municipal (Confirmed)	Housing Area, General (Confirmed)	Pollutant (Confirmed)	Sewage (Confirmed)	Spill (Confirmed)
20072B16	805 E. 4th Ave., Belton, TX	12/4/2007	0	Industry, Other (Confirmed)	Chemical (Suspected), Other (Confirmed)	Pollutant (Confirmed)	Other Petroleum Products (Suspected), Other (Confirmed)	Unregulated Discharge (Confirmed) -- Large amounts of water used to put out fire of large furniture manufacturing warehouse. Runoff into Nolan Creek.
20082A8849	Nolan Creek - 4501 W. Stan Schleuter Loop, Killeen, Tx	12/5/2007	100	Natural Processes (Suspected)	Other Physiological Stress (Suspected)	Low Dissolved Oxygen (Suspected)	Animal Respiration (Suspected)	Natural Processes (Suspected)
20082B30	2604 Waterfall Dr., Killeen, TX	1/27/2008	0	Natural Processes (Suspected)	Other Physiological Stress (Suspected)	Temperature (Suspected)	Cold Front/Freeze (Suspected)	Natural Processes (Suspected)

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218

Event ID	Location	Start Date	Est. Total Killed	General Source	Specific Source	General Cause	Specific Cause	Source Action
20082A10246	Highway 93 - edge of Fort Hood near Belton, TX	2/15/2008		Industry, Transportation (Confirmed)	Land Vehicle (Confirmed)	Pollutant (Confirmed)	Other Petroleum Products (Confirmed)	Collision, Wreck, Etc (Confirmed) - Contaminant = Jet A;
20102A727	Nolan Creek at 38th Street and Water Road	4/27/2010	4152	Municipal (Suspected)	Urban Area, General (Suspected)	Pollutant (Suspected)	Other Petroleum Products (Suspected)	Non-point Source Runoff (Suspected)
20102A10318	Unnamed tributary of Nolan Creek in Killeen - between Lake Dr and Rancier in Longbranch Park	12/9/2010	2080	Municipal (Suspected)	Sewer Lines (Suspected)	Pollutant (Suspected)	Sewage (Suspected)	Unpermitted Discharge (Suspected)
20112A10348	South Nolan Creek between W.S. Young Blvd and 38th Street	2/22/2011	604	Municipal (Confirmed)	Sewer Lines (Confirmed)	Pollutant (Confirmed)	Sewage (Confirmed)	Unpermitted Discharge (Confirmed)
20112A10392	Longbranch Creek at Westcliff Road	4/13/2011	4	Municipal (Confirmed)	Sewer Lines (Confirmed)	Pollutant (Confirmed)	Sewage (Confirmed)	Unpermitted Discharge (Confirmed)
20131A10794	Long Branch Creek at 2019 Dickens Dr. in Killeen	5/3/2013	76	Municipal (Confirmed)	Sewer Lines (Confirmed)	Pollutant (Confirmed)	Sewage (Confirmed)	Unpermitted Discharge (Confirmed)

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218

Event ID	Location	Start Date	Est. Total Killed	General Source	Specific Source	General Cause	Specific Cause	Source Action
20131A10862	Nolan Creek between South Gray Street and 10th Street	7/2/2013	2412	Municipal (Confirmed)	Sewer Lines (Confirmed)	Pollutant (Confirmed)	Sewage (Confirmed)	Unpermitted Discharge (Confirmed) - City of Killeen reported sewage line backed up causing overflow at a lift station. Estimated 40-50,000 gallons of sewage released into the creek.
20131A10838	Florence and Trimmier Ditches, tributaries of Nolan Creek near 202 Cobble Stone Drive	7/23/2013	76	Unknown (Suspected)	Unknown (Suspected)	Pollutant (Suspected)	Chlorine (Suspected) - Chlorine levels were elevated above normal levels in the creek, as determined by chlorine presence/absence test strips (used by city).	Unknown (Suspected)
20131A10951	Little Nolan Creek (Trimmer Ditch)	10/1/2013	591	Municipal (Confirmed)	Sewer Lines (Confirmed)	Pollutant (Confirmed)	Sewage (Confirmed)	Unpermitted Discharge (Confirmed)

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218

Event ID	Location	Start Date	Est. Total Killed	General Source	Specific Source	General Cause	Specific Cause	Source Action
20141A11021	Little Nolan Creek	11/13/2013	771	Industry, Other (Confirmed)	Construction/Building Trades (Confirmed)	Pollutant (Confirmed)	Other (Confirmed) - An incomplete resin curing process resulted in a release of resin products along with process water. An unknown volume of styrene was discharged.	Unpermitted Discharge (Confirmed)
20141A11029	Reese Creek - at the Fort Hood Regional Airport	1/30/2014	257	Industry, Oil and Gas (Confirmed)	Storage Tank (Confirmed)	Pollutant (Confirmed)	Fuel Oil (Confirmed)	Unpermitted Discharge (Confirmed)
20141B11136	Lowe's Ditch, tributary to South Nolan Creek, at 117 Turtle Bend in Killeen	6/17/2014	112	Municipal (Confirmed)	Sewer Lines (Confirmed)	Pollutant (Confirmed)	Sewage (Confirmed)	Unregulated Discharge (Confirmed)
20141B11172	2201 Water Crest Rd., Killeen, TX	11/9/2014	44	Municipal (Confirmed)	Water Lines (Confirmed)	Pollutant (Confirmed)	Chlorine (Confirmed)	Unpermitted Discharge (Confirmed)